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(71) Applicant: SONY CORPORATION
7-35, Kitashinagawa 6-chome
Shinagawa-ku
Tokyo(JP)

(72) Inventor: Ogawa, Tohru, c/o Sony Corporation
7-35, Kitashinagawa 6-chome
Shinagawa-ku, Tokyo(JP)
Inventor: Gocho, Tetsuo, c/o Sony Corporation
7-35, Kitashinagawa 6-chome
Shinagawa-ku, Tokyo(JP)

(74) Representative: TER MEER - MÜLLER - STEINMEISTER & PARTNER
Mauerkircherstrasse 45
D-81679 München (DE)

(54) Method of determining optimum optical conditions for an anti-reflective layer used in a method of forming a resist pattern.

(57) A method of determining an optimum condition of an anti-reflective layer upon forming a resist pattern by exposure with a monochromatic light, a method of forming the anti-reflective layer therewith, a method of forming a resist pattern using a novel anti-reflective layer obtained therewith, and a method of forming a film.

The optimum condition of the anti-reflective layer is determined and the anti-reflective layer is formed by the methods described below. Further, an optimal anti-reflective layer is obtained by the method which is used for forming the resist pattern. The method comprises (I) forming an equi-contour line for the amount of absorbed light regarding a photoresist of an optional film thickness using the optical condition of the anti-reflective layer as a parameter, (II) conducting the same procedure as in (I) above for a plurality of resist film thicknesses, (III) finding a common region for the amount of absorbed light with respect to each of the traces obtained, thereby determining the optical condition for the anti-reflective layer, (IV) applying same procedures as described above while changing the condition of the anti-reflective layer, thereby determining the optical condition for the anti-reflective layer, and (V) determining the optimum optical condition such as the kind and the thickness of the anti-reflective layer under a certain condition of the anti-reflective layer.

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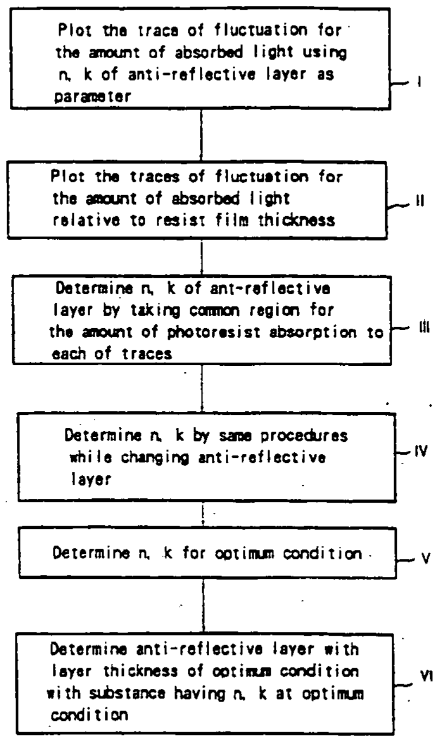
FIG.1

Method of determining optimum condition



The present invention concerns a method of determining conditions for an anti-reflective layer, a method of forming an anti-reflective layer, a method of forming a resist pattern by using a novel anti-reflective layer and a method of forming a film. In particular, it relates to a method of determining a condition of an anti-reflective layer for defining optical conditions such as a thickness and a refractive index condition, for example, reflection refractive index and absorption refractive index of an anti-reflective layer upon forming a resist pattern by exposing a photoresist on an anti-reflective layer formed on an underlying material by a monochromatic light, a method of forming the anti-reflective layer utilizing the above-mentioned method and a method of forming a resist pattern by using a novel anti-reflective layer, and a method of forming a film which can be used the above mentioned method of forming the anti-reflective layer. The present invention can be utilized suitably, for example, to a case of setting an anti-reflective layer disposed for preventing the standing wave effect when photolithography is used or a case of forming a resist pattern by using an anti-reflective layer when photolithography is used upon manufacturing, for example, electronic materials (such as semiconductor devices).

For instance, in the photolithography, a KrF excimer laser beam (248 nm) is used and a lens of about 0.37 to 0.42 NA is mounted in most advanced steppers (projection exposing machine) at present (for example, Nikon NSR 1505 EX1, Canon FPA 4500). By using the steppers, research and development have been studied for design rule devices in a sub-half micron (0.5 um) region.

In the stepper, a monochromatic light is used as an exposing optical source. In a case of exposure by the monochromatic light, it has been generally known that a phenomenon referred to as a standing wave effect occurs. The standing wave is caused by occurrence of light interference in a resist film. That is, it is caused by interference between an incident light P and a reflection light R from the interface between a resist PR and a substrate S in the film of the resist RR.

As a result, as shown in Fig. 19, the amount of light absorbed in the resist (ordinate in the graph) fluctuates depending on the thickness of the resist film (abscissa in the graph). In the present specification, the amount of light absorbed in the resist means an amount of light absorbed in the resist itself excluding the amount of light due to surface reflection, absorption by a metal if it is present in the resist, or light outgoing from the resist. The amount of the absorbed light constitutes an energy for causing light react ion to the resist.

As can be seen from the comparison between Fig. 20 and Fig. 21, the extent of the fluctuation for the amount of the absorbed light differs also depending on the kind of underlying substrates. In Figs. 19, 20 and 21, XP 8843 (manufactured by Shipley Co.) is used in each of the cases and Si, Al-Si and W-Si are used as the underlying material in respective cases. That is, fluctuation for the amount of the absorbed light is determined by a complex swing reflectivity (R) (in which (R) represents that it is a vector amount having a real part and an imaginary part) considering multiple interference determined by optical constants (n, k) of the underlying material (substrate) and optical constants (n, k) of the resist.

Further, in an actual device, as schematically shown in Fig. 22, unevenness is always present to the surface of a substrate. For instance, protrusions In such as poly-Si are present. Therefore, when the resist PR is coated, the thickness of the resist film varies between upper and lower portions of the step. That is, the thickness dPR2 of the resist film on the protrusion In is smaller than the thickness dPR1 of the resist film in other portions than the above. As has been described previously, the standing wave effect differs depending on the thickness of the resist film and, accordingly, fluctuation for the amount of the light absorbed in the resist changes respectively undergoing the effect of the standing wave effect. As a result, the dimension of the resist pattern obtained after exposure and development differs between the upper and the lower portions of the step.

Influence of the standing wave effect on the dimension of the pattern becomes more remarkable as the pattern is finer in a case of using a stepper of an identical wavelength and an identical number of aperture. Figs. 23 - 25 show the influence of the standing wave effect on every pattern dimension in a case of using Nikon NSR 1505 EX1 as a stepper (exposure light used: k = 248 nm, KrF excimer, NA = 0.42) and using XP 8843 as a resist (chemically amplified type resist, a polyvinylphenol type resist containing optical acid generating agent, manufactured by Shipley Microelectronics Co.). It is apparent that the standing wave effect becomes remarkable as the pattern becomes finer (refer also to the scattering of critical dimension shift at 0.5 um, 0.4 um and 0.35 um line-and-space patterns shown by "open circles" in the drawings).

The above-mentioned trend is a phenomenon observed in common with all of resists.

The dimensional accuracy of a resist pattern in a photolithographic step upon manufacturing a device such as a semiconductor device is generally ±5%. Although it is considered that an accuracy coarser than ±5% in total may be practically tolerable. However, it is desirable that the pattern accuracy upon resist exposure is within ±5%, if occurrence of scattering due to other factors such as focus is also taken into consideration. For attaining the dimensional accuracy of ±5%, it is essential to reduce the standing wave effect.

Fig. 26 shows a dimensional variation of the resist pattern relative to the fluctuation (ordinate) for the amount of absorbed light in the resist film (abscissa). As can be seen from Fig. 26, fluctuation for the amount of absorbed light in the resist film has to be within a range of less than 6% in order to manufacture, for example, a rule device of 0.35 um.

For satisfying the above-mentioned requirement, earnest studies have been made on the anti-reflective technique in each of the fields. However, although the material underlying material and the resist to be used are known, it is not always easy to determine as to what are the conditions for the anti-reflective layer that can attain an anti-reflective effect suitable to such a case.

For instance, in the formation of a pattern on a gate structure (for example, on a W-Si film) for which an anti-reflective layer is considered indispensable, it has not yet been determined regarding the condition for the anti-reflective layer that reduces fluctuation for the amount of the absorbed light in the resist film, for example to a range of less than 6%. Naturally, no effective anti-reflective layer material to be used for such W-Si has yet been found.

For the structure using the W-Si material as the gate, a pattern has now been formed at present, for example, by means of a multi-layer resist method or dye-incorporated resist. Accordingly, it is considered essential to establish anti-reflective technique on W-Si as soon as possible.

In such a case, if there is a means capable of determining comprehensive conditions and concrete conditions regarding an anti-reflective layer for forming a stable fine pattern on an optional underlying material (substrate) using an exposure optical source of an optional monochromatic light it can be found for the condition of the anti-reflective layer to be formed, for example, on W-Si. However, no such means has yet been proposed.

The present invention has been achieved in view of the foregoing situations and it is an object thereof to provide a method of determining a condition for an anti-reflective layer capable of determining a condition of the anti-reflective layer used in a case of forming a resist pattern on an optional underlying material (substrate) by using an exposure optical source of an optional monochromatic light, so that a stable resist pattern can be formed satisfactorily even if the resist pattern is fine.

Another object of the present invention is to provide a method of forming an anti-reflective layer by the condition described above.

A further object of the present invention is to provide a method of forming a resist pattern by developing a novel anti-reflective layer and using such an anti-reflective layer.

The foregoing object can be attained in accordance with the first aspect of the present invention by a method of determining a condition for an anti-reflective layer upon forming a resist pattern by exposing a photoresist on the anti-reflective layer formed on an underlying material by a monochromatic light, wherein the film thickness and the optical condition of the anti-reflective layer are determined by the following means, which comprises

(I) determining an equi-contour line for the amount of absorbed light to a photoresist of an optionally determined film thickness using the optical condition for the anti-reflective layer as a parameter,

(II) determining equi-contour lines for the amount of absorbed light for a plurality of resist film thicknesses in the same manner as in (I) above,

(III) finding a common region for the amount of the absorbed light for each of the equi-contour lines obtained in (II) above and setting the optical condition defined by the common region as an optical condition for the anti-reflective layer in the condition defined initially in (I) above,

(IV) determining the optical condition for the anti-reflective layer by conducting the same procedures as described above while changing the condition for the anti- reflective layer and

(V) finding the optimum optical condition for the anti-reflective layer in the condition for the anti-reflective layer according to (IV) above.

The foregoing object can be attained in accordance with the second aspect of the present invention by a method of forming an anti-reflective layer upon forming a photoresist pattern by exposing a photoresist on the anti-reflective layer formed on an underlying material by a monochromatic light, wherein the anti-reflective layer is formed by using a substance adaptable to the optical condition for the refractive index based on the optimum refractive index condition for the anti-reflective layer determined as optimum optical condition by the means (I) - (V) as defined in the first aspect.

The foregoing object can be attained in accordance with the third aspect of the present invention by a method of forming a resist pattern which comprises forming an anti-reflective layer with silicon carbide on an underlying refractory metal silicide material and forming a photoresist on the anti-reflective layer.

The foregoing object can be attained in accordance with the fourth aspect of the present invention by a method of forming a resist pattern by forming an anti-reflective layer on an underlying metalic material and forming a photoresist on the anti-reflective layer thereby forming a resist pattern, wherein the anti-reflective layer is formed with an organic or inorganic substance under the conditions of the film thickness and the optical condition determined by the following means, which comprises:

(I) determining an equi-contour line for the amount of (absorbed) light and dose to a photoresist of an optionally determined film thickness using the optical condition for the anti-reflective layer as a parameter,

(II) determining equi-contour lines for the amount of photoresist absorption for a plurality of resist film thicknesses in the same manner as in (I) above,

(III) finding a common region for the amount of the photoresist absorption for each of the equi-contour lines obtained in (II) above and setting the optical condition defined by the common region as an optical condition for the anti-reflective layer in the condition defined initially in (I) above,

(IV) determining the optical condition for the anti-reflective layer by conducting the same procedures as described above while changing the condition for the anti- reflective layer and

(V) finding the optimum optical condition for the anti-reflective layer in the condition for the anti-reflective layer according to (IV) above.

The foregoing object can be attained in accordance with the fifth aspect of the present invention by a method of forming a resist pattern which comprises forming an anti-reflective layer on an underlying metalic material with silicon carbide or silicon oxide and forming a photoresist on the anti-reflective layer thereby, forming a resist pattern.

The foregoing object can be attained in accordance with the sixth aspect of the present invention by a method of forming an anti-reflective layer on an underlying inorganic material (including metal material and silicon material) and forming a resist pattern on the anti-reflective layer thereby forming the resist pattern, wherein the anti-reflective layer is formed with an organic or inorganic substance satisfying the film thickness and the optical condition determined by the following means, which comprises:

(I) determining an equi-contour line for the amount of photoresist absorption to a photoresist of an optionally determined film thickness using the optical condition for the anti-reflective layer as a parameter,

(II) determining equi-contour lines for the amount of photoresist absorption for a plurality of resist film thicknesses in the same manner as in (I) above,

(III) finding a common region for the amount of the photoresist absorption for each of the equi-contour lines obtained in (II) above and setting the optical condition defined by the common region as an optical condition for the anti-reflective layer in the condition defined initially in (I) above,

(IV) determining the optical condition for the anti-reflective layer by conducting the same procedures as described above while changing the condition for the anti- reflective layer and

(V) finding the optimum optical condition for the anti-reflective layer in the condition for the anti-reflective layer according to (IV) above.

The foregoing object can be attained in accordance with the seventh aspect of the present invention by a method of forming a resist pattern which comprises forming an anti-reflective layer with silicon carbide or silicon oxide on an underlying silicon material and forming a photoresist on the anti-reflective film, thereby forming a resist pattern.

The foregoing object can be attained in accordance with the eighth aspect of the present invention by a method of forming a resist pattern as defined by the fourth aspect, wherein an anti-reflective layer is formed on an underlying metal material by using an organic or inorganic substance having a value within ±0.6 for the reflection refractive index n and a value within ±0.2 for the absorption refractive index k and forming a photoresist on the anti-reflective layer, thereby forming the resist pattern.

The foregoing object can be attained in accordance with the ninth aspect of the present invention by a method of forming a resist pattern, wherein an SiO film having reflection refractive index $n = 2.4 \pm 0.6$ and absorption refractive index $k = 0.7 \pm 0.2$ is used as an anti-reflective layer on an underlying metalic material.

The foregoing object can be attained in accordance with the tenth aspect of the present invention by a method of forming a resist pattern, wherein a $Si_xO_yN_z$ film or a Si_xN_y film having reflection refractive index $n = 2.4 \pm 0.6$ and absorption refractive index $k = 0.7 \pm 0.2$ is used as an anti-reflective layer on the underlying metalic.

The foregoing object can be attained in accordance with the 11th aspect of the present invent ion by a method of forming a resist pattern as defined by any one of the eighth to tenth aspects, where in the underlying metalic material comprises a refractory metal silicide.

The foregoing object can be attained in accordance with the 12th aspect of the present invention by a method of forming a resist pattem, in which a $Si_xO_yN_z$ film is formed as an anti-reflective layer on the underlying metalic material thereby forming a resist pattern.

The foregoing object can be attained in accordance with the 13th aspect of the present invention by a method of forming a resist pattern as defined by the 12th aspect, wherein the metalic material is anyone of aluminum and aluminium alloys.

The foregoing object can be attained in accordance with the 14th aspect of the present invention by a method of forming a resist pattern in which a $Si_xO_yN_z$ or Si_xN_y film as an anti-reflective layer is formed on an underlying silicic material thereby forming a resist pattern.

The foregoing object can be attained in accordance with the 15th aspect of the present invention by a method of forming a resist pattern as defined by the 14th aspect, where in the silicic material comprises any one of single crystal silicon, polycrystal line silicon, amorphous silicon and doped poly-silicon.

The first aspect of the present invention comprises as shown in Fig. 1,

(I) determining an equi-contour line for the amount of photoresist absorption to a photoresist of an optionally determined film thickness using the optical condition for the anti-reflective layer as a parameter,

(II) determining equi-contour lines for the amount of photoresist absorption for a plurality of resist film thicknesses in the same manner as in (I) above,

(III) finding a common region for the amount of the photoresist absorption for each of the equi-contour lines obtained in (II) above and setting the optical condition defined by the common region as an optical condition for the anti-reflective layer in the condition defined initially in (I) above,

(IV) determining the optical condition for the anti-reflective layer by conducting the same procedures as described above while changing the condition for the anti- reflective layer and

(V) finding the optimum optical condition for the anti-reflective layer in the condition for the anti-reflective layer according to (IV) above..

An optimum condition for the anti-reflective layer is obtained in accordance with the foregoing constitution and a substance adaptable to the condition, that is, capable of satisfying or substantially satisfying such a condition is selected thereby enabling to form an effective anti-reflective layer.

For instance, each of refractive indices n, k at each of specific wavelengths (exposure wavelength) is determined by a means such as a spectroscopic ellipsometer and a substance having such refractive indices n, k is searched from existent substances as the anti-reflective material, or a substance for such a condition can be synthesized to serve for the anti-reflective material.

Description will then be made to a methodology of determining a comprehensive condition for an anti-reflective layer by using the present invention with reference to the drawings.

(1) The thickness of the resist film between maximum values or between minimum values of the standing wave effect is given as $k/4n$ assuming the refractive index of the resist as n_{PR} and the exposure wavelength as k (refer to Fig. 2).

(2) An anti-reflective layer ARL is assumed between the resist and the substrate, with the film thickness as d_{ar1} and optical constant as n_{ar1}, k_{ar1}.

(3) Taking notice on the film thickness at a certain point in Fig. 2 (for instance, a film thickness for maximizing the standing wave effect), the amount of the photoresist absorption in the resist film fluctuates at that point as n_{ar1},k_{ar1} are changed while the film thickness d_{ar1} of the anti-reflective layer being fixed. The varying trace, that is, the equi-contour lines for the amount of photoresist absorption is determined as shown in Fig. 3. The procedures described above correspond to (I) in accordance with the present invention.

(4) When the procedure (3) is applied repeatingly to four points each at $k/8n_{PR}$ interval with reference to other different film thickness d_{pr} of the resist, at least, film thickness maximizing or minimizing the standing wave effect, Fig. 4 to Fig. 6 corresponding to Fig. 3 are obtained (in Figs. 3 - 6, the thickness of the anti-reflective layer is defined as 20 nm and the thickness of the resist layer is defined as 985 nm, 1000 nm, 1018 nm and 1035 nm, respectively). This corresponds to the means (II).

(5) The common region for each of the graphs in Fig. 3 to Fig. 6 shows a region in which the amount of absorption in the resist film does not fluctuate even if the resist film thickness varies. That is, the common region described above is a region having a highest anti-reflective effect for minimizing the standing wave effect. Accordingly, such a common region is searched. The common region can be found conveniently, for example, by overlapping each of the graphs to determine the common region (the common region may of course be retrieved by a computer). This corresponds to the means (III).

(6) Procedures (3), (4), (5) are repeated while continuously varying the film thickness d of the anti-reflective layer. For instance, assuming that the procedure was conducted, for example, at d = 20 nm up to (5), then the above-mentioned procedures are repeated while varying d. This can specify the condition for the film thickness d_{ar1} of the anti-reflective layer minimizing the standing wave effect and a condition

for the optical constant n_{ar1}, k_{ar1}. This corresponds to the (IV).

The kind of the film that satisfies the condition to be met by the anti-reflective layer specified in (6) above (film thickness, optical constant) is found by measuring the optical constant of each kind of the films by the exposure light. This corresponds to (V).

This methodology is applicable, in principle, to all of the wavelength and the kind of the underlying material (substrate). Further, an anti-reflective layer of an optimum condition can be formed in accordance with the condition obtained in (7) above and with the substance capable of satisfying the condition (corresponding to Fig. 1(VI)).

By using the method in accordance with the present invention, the anti-reflective layer as an effective means for forming a stable fine pattern on an optional underlying material (substrate) by using a stepper having an optical source of an optional monochromatic light can be designed easily.

The present invention can be utilized for finding a condition of an organic or inorganic film for forming an anti-reflective layer used for forming a stable resist pattern on a W-Si film by using a KrF excimer laser. In this case, a substance having n, k condition shown in Figs. 14 and 15 to be described later can be used. In this case, it is desirable to use such an organic or inorganic layer having a tolerable range for each of n, k values in Figs. 14, 15, i. e. ±0.2 for n and ±0.05 for k. As for the anti-reflective layer, it is preferred to use SiC having n = 3.16 ± 0.2, k = 0.24 ± 0.05 at a film thickness of 50 ± 10 nm. SiC constituting the anti-reflective layer can be formed by sputtering or CVD. SiC can also be etched by RIE using CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 series gas as an etchant and by adding Ar to thereby improve ionic property.

The third through tenth aspects of the present invention can be attained by conducting the operation for finding the substance capable of satisfying the condition as described above by using the above-mentioned method. Referring to the third aspect of the present invention, it can be found that SiC (silicon carbide) is particularly appropriate on refractory metal silicide W-Si, based on which the present invention has been completed.

This invention can suitably be used in a case of forming a stable resist pattern on a W-Si film by using a KrF excimer laser, in which SiC with n = 3.16 ± 0.2 and k = 0.24 ± 0.05 at a film thickness of 50 ± 10 nm is preferably used as the anti-reflective layer. SiC constituting the anti-reflective layer can be formed by sputtering or CVD. SiC can be etched by RIE using CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 gas as an etchant and by adding Ar to improve the ionic property.

Further, in the fourth aspect of the present invention, the concept of the first aspect is applied in a case of using a metalic material such as a refractory metal compound as the underlying material.

Referring to the fifth aspect of the present invention, upon forming a resist pattern by forming a resist on an anti-reflective layer, when an operation of finding out the substance capable of satisfying the condition in accordance with the condition obtained by the above-mentioned method is conducted, it has been found that SiC (silicon carbide) and SiO (silicon oxide) are suitable on a metalic wiring material, particularly, Al and Al-alloys material, for example, Al, Al-Si, Al-Si-Cu or Cu and Cu-alloys material such as Cu, as well as that an organic or inorganic material found by the above-mentioned method is appropriate, based on which the present invent ion has been attained.

This invention is preferably applied in a case of forming a stable resist pattern on an Al or al-alloys material such as Al, Al-Si or Al-Si-Cu or a Cu or Cu-alloys material such as Cu by using a KrF excimer laser. In this case, it is preferred to use SiO with n = 1.83 ± 0.2 and k = 0.75 ± 0.2 at a layer thickness of 30 ± 10 nm as an anti-reflective layer, for example, on the Al or Al-alloys material. Alternatively, SiC with n = 2.3 ± 0.2 and k = 0.8 ± 0.2 is preferably used at a layer thickness of 20 ± 10 nm. Alternatively, it is preferred to use an organic or inorganic substance having an optimum curve regarding the refractive index and the layer thickness of the anti-reflective layer obtained in (V) above, and within a range of the value on the curve ±0.2 for n and the value on the curve ±0.15 for k. SiO constituting the anti-reflective layer can be formed by CVD or thermal oxidation. SiC can be formed by sputtering or CVD. The anti-reflective layer can be etched by RIE using CF_4, CHF_3, C_2F_6, C_3H_8, SF_6 or NF_3 series gas as an etchant and adding Ar and O_2 to improve the ionic property.

In the sixth aspect of the present invention, the concept of the first aspect is applied in a case of using an inorganic substance such as silicic material as an underlying material.

Referring to the seventh aspect of the present invention, when an operation was conducted in accordance with the condition obtained in the foregoing method and finding a substance capable of satisfying the condition, it has been found that SiC (silicon carbide) or SiO is appropriate on a silicic material, particularly, a silicon substrate, based on which the present invention has been attained.

This invention can suitably be applied to a case of forming a stable resist pattern on a silicon substrate by using a KrF excimer layer. In this case, it is preferred to use SiC with n = 2.3 ± 0.2 and k = 0.65 ± 0.2 at a layer thickness of 25 nm ± 10 nm as an anti-reflective layer. Alternatively, it is preferred to use SiO with n = 2.1 ± 0.2 and k = 0.7 ± 0.2 at a layer thickness of 30 ± 10 nm. SiO constituting the anti-reflective layer can be formed, for example, by CVD or thermal oxidation. SiC can be formed, for example, by sputtering or CVD. The anti-reflective layer can be etched by RIE using CF_4, CF_3, C_2F_6, C_3H_8, SF_6 or NF_3 series gas as an etchant and adding Ar and O_2 or Ar or O_2 to improve the ionic property.

Referring to the ninth and tenth aspects of the present invent ion, it has been found that a SiO_x film, SiO_xN_z film or SiN_y film is appropriate on a metal material such as refractory metal silicide in accordance with the condition obtained by the method as described above, based on which the present invention has been attained.

This invention is applicable preferably to a case of forming a stable resist pattern on a W-Si film by using a KrF excimer laser. In this case, as the anti-reflective layer, it is preferred to use SiO_x with n = 2.4 ± 0.6and k = 0.7 ± 0.2 at a layer thickness of 30 ± 10 nm and further, SiO_x can be formed by various kinds of CVD processes. Further, SiO_x can be etched by RIE using CHF_3, C_4F_8, CHF_3 or S_2F_2 gas as an etchant and improving the ionic property.

Referring to 12th and 13th aspects of the present invention, it has been found that a SiO_xN_y film is suitable on the underlying metalic material such as Al and Al-alloys material, based on which the present invention has been attained.

Further, referring to the 14th and 15th aspects of the present invention, it has been found that a SiO_xN_y film or Si_xN_y film is appropriate on the silicon series underlying material, based which the present invention has been attained.

Fig. 1 is a flow chart illustrating the constitution for the method of determining an optimum condition according to the present invention:

Fig. 2 is a view illustrating a standing wave effect;

Fig. 3 is a view illustrating a trace of fluctuation for the amount of absorbed dose in a resist film (an equicontour line for the amount of photoresist absorption) in a case where n_{ar1}, k_{ar1} are varied while fixing the thickness of the anti-reflective layer ARL, with respect to a certain resist film thickness:

Fig. 4 is a view illustrating a trace (equi-contour line) for other film thickness of the resist;

Fig. 5 is a view illustrating a trace (equi-contour line) for other film thickness of the resist:

Fig. 6 is a view illustrating a trace (equi-contour line) for other film thickness of the resist:

Fig. 7 is a view illustrating the standing wave effect to be solved:

Fig. 8 shows a trace of fluctuation for the amount of absorbed light in the resist film relative to variation of n_{ar1}, k_{ar1}, (equi-contour lines of photoresist absorption amount) for the resist film thickness of 985 nm in a case where the thickness of the anti-reflective layer is 30 nm:

Fig. 9 is a view illustrating a trace (equi-contour lines) for the resist film thickness of 1000 nm:

Fig. 10 is a view illustrating the trace (equi-contour lines) for the resist film thickness of 1017.5 nm:

Fig. 11 is a view illustrating the trace (equi-contour lines) for the resist film thickness of 1035 nm;

Fig. 12 is a view illustrating the standing wave effect at the optimum condition (Example 1);

Fig. 13 is a view illustrating the standing wave effect at the optimum condition (Example 1);

Fig. 14 is a view illustrating a relationship between the thickness of the anti-reflective layer and n as the optical condition:

Fig. 15 is a view illustrating a relationship between the thickness of the anti-reflective layer and k as the optical condition;

Fig. 16 is a n, k chart for finding the optimum anti-reflective layer material;

Fig. 17 is a view illustrating the anti-reflective effect of SiC (50 nm film thickness) on W-Si in comparison with the prior art;

Fig. 18 is a view for the explanation of a problem in the prior art, which shows the interference of light in the resist film;

Fig. 19 is a view for the explanation of a problem in the prior art, which shows the standing wave effect;

Fig. 20 is a view for the explanation of a problem in the prior art, which shows the standing wave effect;

Fig. 21 is a view for the explanation of a problem in the prior art, which shows the standing wave effect;

Fig. 22 is a view for the explanation of a problem in the prior art, which shows the effect of a step;

Fig. 23 is a view illustrating the effect of the standing wave effect;

Fig. 24 is a view illustrating the effect of the standing wave effect;

Fig. 25 is a view showing the effect of the standing wave effect;

Fig. 26 is a view illustrating a relationship between the fluctuation for the amount of absorbed light and the dimensional variation of the pattern;

Fig. 27 is a cross sectional view for a portion illustrating the structure of Example 7;

Fig. 28 is a cross sectional view for a portion illustrating the structure of Example 14;

Fig. 29 is a view illustrating the standing wave effect;

Fig. 30 shows a trace of fluctuation for the amount of absorbed light in the resist film relative to variation of n_{ar1}, k_{ar1}, (equi-contour lines of absorbed light amount) for the resist film thickness of 982 nm in a case where the thickness of the anti-reflective layer is 30 nm;
Fig. 31 is a view illustrating the trace (equi-contour lines) for the resist film thickness of 1000 nm;
Fig. 32 is a view illustrating the trace (equi-contour lines) for the resist film thickness of 1018 nm;
Fig. 33 is a view illustrating the trace (equi-contour lines) for the resist film thickness of 1035 nm;
Fig. 34 is a view illustrating the standing wave effect at the optimum condition;
Fig. 35 is a view illustrating the standing wave effect at the optimum condition;
Fig. 36 is a view illustrating a relationship between the film thickness and k as the optical condition of the anti-reflective film;
Fig. 37 is a view illustrating the dependence of n, k values of the SiC film on the film forming condition;
Fig. 38 is a view illustrating the anti-reflective effect of SiC (20 nm film thickness) on Al, Al-Si, Al-Si-Cu in comparison with a comparative case;
Fig. 39 is a view illustrating the anti-reflective effect of SiO (30 nm film thickness) on Al, Al-Si, Al-Si-Cu in comparison with the comparative case;
Fig. 40 is a cross sectional view for a portion illustrating the structure of Example 34;
Fig. 41 is a view illustrating the standing wave effect;
Fig. 42 is a view illustrating the anti-reflective effect of a SiC film (25 nm) on a silicon substrate in comparison with a comparative case;
Fig. 43 is a view illustrating the anti-reflective effect of a SiO film (30 nm) on a silicon substrate in comparison with a comparative case;
Fig. 44 is a cross sectional view illustrating the structure of Example 43;
Fig. 45 is a view illustrating the behavior of SiO film formation by CVD;
Fig. 46 is a view illustrating the anti-reflective effect of SiO (24 nm) on W-Si;
Fig. 47 is a cross sectional view illustrating the structure of Example 53;
Fig. 48 is a view illustrating the behavior in forming a $Si_xO_yN_z$ film by CVD;
Fig. 49 is a view illustrating the anti-reflective effect of $Si_xO_yN_z$ (25 nm) on W-Si;
Fig. 50 is a cross sectional view illustrating the structure of Example 65;
Fig. 51 is a view illustrating the optical constant property of $Si_xO_yN_z$ or Si_xn_y;
Fig. 52 is a view illustrating the standing wave effect at the optimum condition in Example 65;
Fig. 53 is a cross sectional view showing the structure of Example 77;
Fig. 54 is a view illustrating the anti-reflective effect of a $Si_xO_yN_z$ film or Si_xN_y film (32 nm) on Si;
Fig. 55 is a view illustrating the anti-reflective effect of a $Si_xO_yN_z$ film or Si_xN_y film (100 nm) on Si;
Fig. 56 is a view illustrating the optical constant property of $Si_xO_yN_z$ or Si_xN_y; and
Fig. 57 is a view illustrating the anti-reflective effect of the $Si_xO_yN_z$ film or Si_xN_y film (33 nm) on the Si series material.
Fig. 58 is a view illustrating Example, which shows relationship between current ratio SiH_1/N_2O and n, k value of the formed film of SiOxNy.
Fig. 59 is a view illustrating Example 90, which shows relationship between current ratio SiH_4/N_2U and element ratio of Si. O. N. H (RBS value) of the formed film of SiOxNy.
Fig. 60 is a view illustrating IR spectrum of film formed in Example 90.
Fig. 61 is a view illustrating ordinarily used current ratio of SiH_4/N_2O for forming SiOxNy film.
Fig. 62 is a view illustrating the anti-reflective effect of the film formed in Example 90.
Fig. 63 is a view illustrating the anti-reflective effect of the film formed in Example 90.
Fig. 64 is a view illustrating the anti-reflective effect of the film formed in Example 90.
Fig. 65 is a view illustrating the anti-reflective effect of the film formed in Example 90.
Fig. 66 is a view illustrating the anti-reflective effect of the film formed in Example 90.
Fig. 67 is a view illustrating the operation of Example 90.
Fig. 68 is a view illustrating the operation of Example 90.

EXAMPLE

Description will now be made specifically to examples of the present invention. However, the present invention is not limited by the following examples.

Example 1

In this example, the present invention is applied to determination of conditions to be satisfied by an anti-reflective layer (layer thickness, optical constant) for forming a stable pattern on a W-Si film by using KrF excimer lithography. This example is practiced in accordance with the following steps (1) - (6).

(1) Fig. 7 shows a standing wave effect when XP 8843 resist (Shipley Microelectronics Co.) was coated on a W-Si film without an anti-reflective layer and exposed by an KrF excimer laser beam at a wave length of 248 nm, followed by development. From Fig. 7, the standing wave effect was about ±20%.

(2) In Fig. 7, the maximum value of the standing wave effect is at a resist film thickness, for example, of 985 nm. Fig. 8 shows the fluctuation for the amount of photoresist absorption in the resist film relative to the change of optical constants n_{ar1} and k_{ar1} of the anti-reflective layer (equi-contour lines for the amount of photoresist absorption), taking notice on the resist film thickness of 985 nm and setting the layer thickness of the anti-reflective layer at 30 nm.

(3) Figs. 9, 10 and 11 show the results of repeating the procedures (2) above to each of the resist film thicknesses of 1,000 nm, 1,017.5 nm and 1,035 nm, respectively.

(4) As a result of determining a common region of Figs. 8 - 11,

n_{ar1} = 4.9, k_{ar1}, = 0.1, or

n_{ar1} = 2.15, k_{ar1} = 0.67

were obtained.

That is, the condition to be satisfied by the optimum anti-reflective layer with the thickness of the anti-reflective layer being set as 30 nm is;

n_{ar1} = 4.9, k = 0.1, or

n_{ar1} = 2.15, k_{ar1} = 0.67

When the standing wave effect was determined by using the above-mentioned condition, the results shown in Figs. 12 and 13 were obtained. In Figs. 12 and 13, the standing wave effect was extremely small and it was about ±1% in each of the cases. The standing wave effect was reduced to about 1/20 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were conducted in a case of setting the thickness of the anti-reflective layer as 30 nm. When the procedures (2) - (4) were repeated also for other different layer thicknesses of anti-reflective layers (ARL thickness), an optimum condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer can be determined. Figs. 14 and 15 show the obtained results.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above is present or not, by using a spectroscopic ellipsometer ("MOSS System" manufactured by SOPRA Co.) and "Handbook of Optical Constants of Solids" (E. D. Palik, Academy press, 1985). As a result, a n, k chart shown in Fig. 16 was obtained. Substances having corresponding n, k are shown on the chart. From Fig. 16, it has been found that SiC (silicon carbide) at 50 nm can completely satisfy the conditions in Figs. 14 and 15. Fig. 17 shows the standing wave effect in the case of using SiC at 50 nm thickness as an anti-reflective layer on W-Si and in a case of not using the anti-reflective layer. In a case of using SiC at 50 nm as the anti-reflective layer (graph for "with ARL" in the figure), the standing wave effect was ± 1%, which was reduced to about 1/20 as compared with the case of not using the anti-reflective layer (graph for "without ARL" in the figure).

Example 2

In this example, anti-reflective layer was formed by forming a SiC film with n = 3.16 ± 0.2 and k = 0.24 ± 0.1 shown in Example 1 by the following method.

That is, in this example, a film was formed by utilizing a thermal CVD process at a temperature of 100°C to 1500° and under a pressure of 0.01 to 10,000 Pa by using the following gas as the starting material gas:

$SiCl_4 + C_3H_8 + H_2$,
$SiHCl_3 + C_3H_8 + H_2$,
$SiH_4 + C_3H_8 + H_2$,
$SiH_4 + C_2H_4 + H_2$,
$SiH_4 + C_3H_8 + H_2$,
$SiCl_3 + CH_3 + H_2$,
$SiH_4 + C_3H_8 + H_2$ or

$SiH_4 + C_3H_8 + H_2$.

Thus, SiC film having an aimed anti-reflective effect could be obtained.

Example 3

In this Example, a SiC film was formed as below to obtain an anti-reflective layer.

That is in this example, a film was formed by utilizing a plasma CVD process and using a photochemical reaction from a gas mixture comprising: $Si_2H_6 + Si(CH_3)H_3 + C_2H_2$.

Example 4

In this example, a SiC film was formed as below to obtain an anti-reflective layer.

A film was formed by utilizing an ECR plasma process and using a microwave (2.45 GHz) from a gas mixture comprising: $SiH_4 + CH_4 + H_2$.

Example 5

In this example, a SiC film was formed as below to obtain an anti-reflective layer. That is, a film was formed by utilizing a sputtering method using SiC as a target.

Example 6

In this example, an anti-reflective layer was formed by patterning a SiC film by etching.

In this case, the SiC film was etched by a reactive ion etching process using a CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 series gas as an etchant and adding Ar to improve the ionic property, thereby obtaining an anti-reflective layer of a desired pattern.

Example 7

In this example, the present invention was applied by using SiC as an anti-reflective layer for forming a stable pattern on a W-Si film using KrF excimer lithography.

In the method of forming a resist pattern in this example, as shown in Fig. 27, an anti-reflective layer ARL was formed with silicon carbide on a W-Si underlying material which was a refractory metal silicide and a photoresist PR was formed on the anti-reflective layer ARL, thereby forming a resist pattern.

In this example, the present invention is applied by using SiC as the anti-reflective layer ARC, particularly, in a case of forming a material layer with W-Si as a gate, on a substrate 1 such as a Si semiconductor substrate and patterning the same by a photolithographic step using a photoresist PR and an etching step, thereby obtaining a gate structure.

At first, description will be made to procedures for selecting SiC as the anti-reflective layer to be used on W-Si and a method of determining a condition to be satisfied by SiC. The following procedures (1) - (6) were conducted.

(1) XP 8843 resist (Shipley Microelectronics Co.) was coated on a W-Si film without an anti-reflective layer, which was exposed by an KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 7 shows a standing wave effect in this case. From Fig. 7, the standing wave effect was about ±20%.

(2) In Fig. 7, the maximum value of the standing wave effect is at a resist film thickness, for example, of 985 nm. Fig. 8 shows fluctuation for the amount of photoresist absorption in the resist film relative to the change of optical constants n_{ar1} and k_{ar1} of the anti-reflective layer, taking notice on the resist film thickness of 985 nm and setting the layer thickness of the anti-reflective layer to 30 nm.

(3) Figs. 9, 10 and 11 show the results of repeating the procedures (2) above to each of the resist film thicknesses of 1,000 nm, 1,017.5 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Figs. 8 - 11,

$n_{ar1} = 4.9$ $k_{ar1} = 0.1$, or

$n_{ar1} = 2.15$, $k_{ar1} = 0.67$

were obtained.

That is, the condition to be satisfied by the optimum anti-reflective layer with the thickness of the anti-reflective layer being set as 30 nm is:

n_{ar1} = 4.9, k_{ar1} = 0.1, or
n_{ar1} = 2.15, k_{ar1} = 0.67.

When the standing wave effect was determined by using the above-mentioned condition, the results shown in Figs. 12 and 13 were obtained. In Figs. 12 and 13, the standing wave effect was extremely small and it was about ±1% in each of the cases. The standing wave effect was reduced to about 1/20 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were conducted in a case of setting the thickness of the anti-reflective layer as 30 nm. When the procedures (2) - (4) were repeated also for other different layer thicknesses of anti-reflective layer (ARL thickness), an optimum condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer could be determined. Figs. 14 and 15 show the obtained results.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above is present or not by using a spectroscopic ellipsometer ("MOSS System" manufactured by SOPRA Co.) and "Handbook of Optical Constants of Solids" (E. D. Palik, Academy press, 1985). As a result, a n, k chart shown in Fig. 16 was obtained. Substances having corresponding n, k are shown on the chart. From Fig. 16, it has been found that SiC (silicon carbide) at 50 nm can completely satisfy the conditions in Figs. 14 and 15. Fig. 17 shows the standing wave effect in a case of using SiC at 50 nm thickness as the anti-reflective layer on W-Si and in a case of not using the anti-reflective layer. In a case of using SiC at 50 nm as the anti-reflective layer (graph for "with ARL" in the figure), the standing wave effect was ±1%, which was reduced to about 1/20 as compared with the case of not using the anti-reflective layer (graph for "without ARL" in the figure).

Example 8

In this example, an anti-reflective layer was formed by forming a SiC film with n = 3.16 ± 0.2 and k = 0.24 ± 0.1 shown in Example 1 by the following methods.

That is, in this example, a film was formed by utilizing a thermal CVD process at a temperature of 100°C to 1500° and under a pressure of 0.01 to 10,000 Pa by using the following gas as the starting material.

$SiCl_4 + C_3H_8 + H_2$,
$SiHCl_3 + C_3H_8 + H_2$,
$SiH_4 + C_3H_8 + H_2$,
$SiH_4 + C_2H_4 + H_2$,
$SiH_4 + C_3H_8 + H_2$,
$SiCl_3 + CH_3 + H_2$,
$SiH_4 + C_3H_8 + H_2$ or
$SiH_4 + C_3H_8 + H_2$.

Thus, a SiC films having aimed anti-reflective effect could be obtained.

Example 9

In this Example, a SiC film was formed as below to obtain an anti-reflective layer.

That is, in this example, a film was formed by utilizing a plasma CVD process and using a photochemical reaction for a gas mixture comprising: Si_2H_6 + $Si(CH_3)H_3$ + C_2H_2.

Example 10

In this example, a SiC film was formed as blow to obtain an anti-reflective layer.

A film was formed by utilizing an ECR plasma process and using a microwave (2.45 GHz) from a gas mixture comprising: $SiH_4 + CH_4 + H_2$.

Example 11

In this example, a film was formed by utilizing an ECR plasma CVD process from $SiH_4 + C_2H_4$ gas by a plasma process using a microwave at 2.45 GHz.

Example 12

A SiC film was formed as below to obtain an anti-reflective layer.

A film was formed by a sputtering method using SiC as a target.

Example 13

In this Example, an anti-reflective layer was formed by patterning a SiC film by etching.

In this case, the SiC film was etched by a reactive ion etching process using CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 series gas (or a mixed gas system) as an etchant and adding Ar to improve the ionic property, thereby obtaining an anti-reflective layer of a desired pattern.

Example 14

In this example, the present invention was applied by using SiC as the anti-reflective layer for forming a stable pattern on an Al, Al-Si or Al-Si-Cu film as the Al series material using KrF excimer lithography.

As shown in Fig. 28, in the method of forming the resist pattern in this example, an anti-reflective layer ARL was formed with silicon carbide on Al, Al-Si or Al-Si-Cu as an Al or Al-alloys metalic wiring material (1) and forming a photoresist PR on the anti-reflective layer ARL thereby forming a resist pattern.

In this example, the present invention was applied, particularly, in a case of obtaining a wiring structure by forming a material layer as wiring with Al, Al-Si or Al-Si-Cu on a substrate S such as a Si semiconductor substrate, and patterning the same by a photolithographic step using the photoresist PR and an etching step, in which SiC was used as the anti-reflective layer ARC. As Al-Si, there can be preferably used, in addition to a generally used Al-Si alloy containing 1 wt% Si generally used, an alloy with lower or higher Si content. This example is preferably applicable to Al-Si-Cu in which Si is about 1 wt% and Cu is about 0.1 to 2 wt%, with no particular restriction only thereto. Typically, Al-Si-Cu alloy of 1 wt% Si, 0.5 wt% Cu is used.

At first, description will be made to procedures for selecting SiC as an anti-reflective layer used on Al, Al-Si or Al-Si-Cu as the Al or Al-alloys, as well as a method of determining the condition to be satisfied by SiC. The following procedures (1) - (6) were conducted.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on an Al, Al-Si or Al-Si-Cu film without an anti-reflective layer and exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 29 shows the standing wave effect in this case. As shown in Fig. 29, the standing wave effect was about ± 29.6%.

(2) In Fig. 29, the maximum value of the standing wave effect situates, for example, at 982 nm of the resist film thickness. Fig. 30 shows fluctuation for the amount of photoresist absorption in the resist film relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, (equi-contour lines for the amount of absorbed light) 30, taking notice on the resist film at a thickness of 982 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) Figs. 31, 32 and 33 show results of repeating the procedure (2) described above to the resist film thicknesses of 1,000 nm, 1,018 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Fig. 30 to Fig. 33,

$n_{ar1} = 4.8$, $k_{ar1} = 0.45$ or

$n_{ar1} = 2.0$, $k_{ar1} = 0.8$

was obtained.

That is, the condition to be satisfied by the optimum anti-reflective layer upon setting the thickness of the anti-reflective layer as 30 nm was:

$n_{ar1} = 4.8$, $k_{ar1} = 0.45$ or

$n_{ar1} = 2.0$, $k_{ar1} = 0.8$.

When the standing wave effect was determined by using this condition, results shown by "optimum condition" in Fig. 34 and Fig. 35 were obtained. As apparent from the comparison with "without anti-reflective layer" in Figs. 34 and 35, the standing wave effect was extremely small, which was about less than ±1% in each of the cases. As compared with the case without anti-reflective layer, the standing wave effect was reduced to about 1/30.

(5) The procedures (2) - (4) above are for the case of setting the thickness of the anti-reflective layer to 30 nm. When the procedures (2) - (4) were repeated also to the anti-reflective layers of different thicknesses (ARL thickness), the optimum condition for the anti-reflective layer depending on the thickness of the anti-reflective layer was determined. Figs. 14 and 36 show the thus obtained results are shown.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer obtained in (5) described above are present or not, by using a spectroscopic ellipsometer ("Moss System", manufactured by SOPRA Co.) and "Handbook of Optical Contacts of Solids" (E.D. Palik, Academy press, 1985). As a result, a n, k chart was obtained as shown in Fig. 16. Substances having corresponding n, k are shown on the chart. From Fig. 16, it has been found that SiC (silicon carbide) at 20 nm can completely satisfy the conditions in Fig. 14 and 36. Fig. 38 shows the standing wave effect in a case of using or not using SiC at 20 nm as an anti-reflective layer on Al, Al-Si or Al-Si-Cu. The standing wave effect in a case of using SiC at 20 nm as the anti-reflective layer (graph for "with ARL" in Fig. 38) was ±2.2 (1.4%) and the standing wave effect was reduced to about 1/15 compared with the case of not using the anti-reflective layer (graph for "without ARL" in the figure). Fig. 37 shows the dependence of n, k values of the SiC film on the film forming condition.

Example 15

In this example, an anti-reflective layer as shown in Fig. 28 was formed by forming a SiC film with n = 2.3 ± 0.2 and k = 0.8 ± 0.2 shown in Example 1 by the following method.

That is, in this example, a film was formed by utilizing a thermal CVD process at a temperature of 100°C to 1500° and usually under a pressure, preferably, 0.01 to 10,000 Pa, more preferably, 100 to 10,000 Pa by using the following gas as the starting material gas:

$SiCl_4$ + C_3H_8 + H_2,
$SiHCl_3$ + C_3H_8 + H_2,
SiH_4 + C_3H_8 + H_2,
SiH_4 + C_2H_4 + H_2,
SiH_4 + C_3H_8 + H_2,
$SiCl_3$ + CH_3 + H_2,
SiH_4 + C_3H_8 + H_2 or
SiH_4 + C_3H_8 + H_2.

Thus, a SiC film having an aimed anti-reflective effect could be obtained.

Example 16

In this Example, a SiC film was formed as below to obtain an anti-reflective layer. That is, in this example, a film was formed by utilizing a plasma CVD process and using a photochemical reaction in a gas mixture comprising: Si_2H_6 + $Si(CH_3)H_3$ + C_2H_2.

Example 17

In this example, a SiC film was formed as below to obtain an anti-reflective layer.

A film was formed by an ECR plasma process by utilizing an ECR plasma CVD process using a microwave (at 2.45 GHz) from a gas mixture comprising: SiH_4 + CH_4 + H_2, SiH_4 + C_2H_4 + H_2 or SiH_4 + CH_4 + H_2.

Example 18

In this example, an SiC film was formed as below to obtain an anti-reflective layer. That is, a film was formed by utilizing a sputtering method using SiC as a target.

Example 19

In this example, an anti-reflective layer was formed by patterning a SiC film by etching.

In this case, the SiC film was etched by a reactive ion etching process using a CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 gas as an etchant and adding Ar to improve the ionic property, thereby obtaining an anti-reflective layer of a desired pattern.

Example 20

In this example, the present invention was applied by using SiO as an anti-reflective layer for forming a stable pattern on an Al, Al-Si or Al-Si-Cu film using KrF excimer lithography.

In the method of forming a resist pattern in this example, as shown in Fig. 28, an anti-reflective layer ARL was formed with silicon oxide SiO on an Al, Al-Si or Al-Si-Cu as the Al or Al-alloys metal wiring material and a photoresist PR was formed on the anti-reflective layer ARL, thereby forming the resist pattern.

In this example, the present invention was applied by using SiO as the anti-reflective layer ARL, particularly, in a case of forming a material layer as wiring with Al, Al-Si or Al-Si-Cu on a substrate S such as a Si semiconductor substrate and patterning the same by a photolithographic step using a photoresist PR and an etching step, thereby obtaining a gate structure.

At first, description will be made to procedures for selecting SiO as the anti-reflective layer to be used on Al, Al-Si or Al-Si-Cu as the Al or Al-alloys material and a method of determining a condition to be satisfied by SiO. The following procedures (1) - (6) were conducted in the same manner as in Example 14.

(1) XP 8843 resist (Shipley Microelectronics Co.) was coated on an Al, al-Si or Al-Si-Cu film without an anti-reflective layer and exposed by an KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 29 shows a standing wave effect in this case. From Fig. 29, the standing wave effect was about ±29.6%.

(2) In Fig. 29, the maximum value of the standing wave effect is at a resist film thickness, for example, of 982 nm. Fig. 30 shows fluctuation for the amount of absorbed dose in the resist film relative to the change of optical constants n_{ar1} and k_{ar1} of the anti-reflective layer, taking notice on the resist film thickness of 982 nm and setting the layer thickness of the anti-reflective layer to 30 nm.

(3) Figs. 31, 32 and 33 show the results of repeating the procedures (2) above to each of the resist film thicknesses of 1,000 nm, 1,018 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Figs. 30 to 33,

n_{ar1} = 4.8, k_{ar1} = 0.45, or

n_{ar1} = 2.0, k_{ar1} = 0.8

were obtained.

That is, the condition to be satisfied by the optimum anti-reflective layer with the thickness of the anti-reflective layer being set as 30 nm is:

n_{ar1} = 4.8, k_{ar1} = 0.45, or

n_{ar1} = 2.0, k_{ar1} = 0.8.

When the standing wave effect was determined by using the above-mentioned condition, the results shown in Fig. 34 and Fig. 35 as described in Example 14 were obtained. In Fig. 34 and Fig. 35, the standing wave effect was extremely small and it was about less than ±1% in each of the cases. The standing wave effect was reduced to about 1/30 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were conducted in a case of setting the thickness of the anti-reflective layer as 30 nm. When the procedures (2) - (4) were repeated also for anti-reflective layer (ARL thickness) of other different layer thicknesses, an optimum condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer could be determined. Fig. 14 and Fig. 36 show the obtained results.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above are present or not by using a spectroscopic ellipsometer ("MOSS System" manufactured by SOPRA Co.) and "Handbook of Optical Constants of Solids" (E.D. Palik, Academy press, 1985). As a result, a n, k chart shown in Fig. 16 was obtained. Substances having corresponding n, k are shown on the chart. From Fig. 16, it has been found that SiO (silicon oxide) at 30 nm can completely satisfy the conditions in Fig. 14 and Fig. 36. Fig. 39 shows the standing wave effect in a case of using SiO at 30 nm thickness as the anti-reflective layer on Al, Al-Si or Al-Si-cu and in a case of not using the anti-reflective layer. In a case of using SiO at 30 nm as the anti-reflective layer (graph for "with SiO" in the figure), the standing wave effect was ±2.2% (1.4%), which was reduced to about 1/20 as compared with the case of not using the anti-reflective layer (graph for "without SiO" in the figure).

Example 21

In this example, an anti-reflective layer was formed by forming a SiO film with n = 1.83 ± 0.2 and k = 0.75 ± 0.2 shown in Example 20 by the following method.

That is, in this example, a film was formed at a temperature from normal temperature to 500° and under a pressure of 0.01 to 10 Pa by using a gas mixture of $SiH_4 + O_2 + N_2$. Thus, a SiO film having an aimed anti-reflective effect could be obtained.

Example 22

In this Example, an anti-reflective layer was formed by patterning a SiO film by etching.

In this case, the SiO film was etched by a reactive ion etching process using CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 series gas (or a mixed gas system) as an etchant and adding Ar to improve the ionic property, thereby obtaining an anti-reflective layer of a desired pattern.

Example 23

In this example, an organic or inorganic substance suitable for forming a stable pattern on an Al, Al-Si or Al-Si-Cu film was obtained and using it as an anti-reflective layer by using KrF excimer lithography.

As shown in Fig. 28, in the method of forming the resist pattern in this example, an anti-reflective layer ARL was formed on Al, Al-Si or Al-Si-Cu as an Al or Al-alloys wiring material (1) and forming a photoresist PR on the anti-reflective layer ARL, thereby forming a resist pattern, in which an appropriate material was selected to form the anti-reflective layer.

In this example, the anti-reflective layer was designed, particularly, in a case of obtaining a wiring structure by forming a material layer as wiring with Al, Al-Si or Al-Si-Cu on a substrate S such as a Si semiconductor substrate, and patterning the same by a photolithographic step using the photoresist PR and an etching step.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on an Al, Al-Si or Al-Si-Cu film without an anti-reflective layer and exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 29 shows the standing wave effect in this case. As shown in Fig. 29, the standing wave effect was about ± 29.6%.

(2) In Fig. 29, the maximum value of the standing wave effect situates, for example, at 982 nm of the resist film thickness. Fig. 30 shows fluctuation for the amount of photoresist absorption in the resist film relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, taking notice on the resist film at a thickness of 982 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) Figs. 31, 32 and 33 shows the results of repeating the procedure (2) described above to each of resist film thicknesses of 1,000 nm, 1,018 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Fig. 30 to Fig. 33,

n_{ar1} = 4.8, k_{ar1} = 0.45 or

n_{ar1} = 2.0, k_{ar1} = 0.8

was obtained.

That is, the condition to be satisfied by the optimum anti-reflective layer upon setting the thickness of the anti-reflective layer as 30 nm was;

n_{ar1} = 4.8, k_{ar1} = 0.45 or

n_{ar1} = 2.0, k_{ar1} = 0.8.

When the standing wave effect was determined by using this condition, results shown in Fig. 34 and Fig. 35 were obtained. The standing wave effect shown by "optimum condition" in Figs. 34 and 35 was extremely small, which was about less than ±1% in each of the cases. As compared with the case without anti-reflective layer, the standing wave effect was reduced to about 1/30.

(5) The procedures (2) - (4) above are for the case of setting the thickness of the anti-reflective layer to 30 nm. When the procedures (2) - (4) were repeated also to the anti-reflective layers of different thicknesses (ARL thickness), the optimum condition for the anti-reflective layer depending on the thickness of the anti-reflective layer was determined. Figs. 14 and 36 show the thus obtained results.

The standing wave effect was reduced to less than ±3% by using an organic or inorganic substance capable of satisfying the optical property on the curve in Figs. 14 and 36, or within a range of a value on the curve ±0.2 for n and a value on the curve ±0.15 for k. Accordingly, such an organic or inorganic substance was determined to form an anti-reflective layer. As compared with the case of not using the anti-reflective layer, the standing wave effect was reduced to about 1/10.

Examples 24 - 33

In these examples, Cu wiring was formed by using Cu as the Cu or Cu-alloys material instead of the Al or Al-alloys metal material such as Al, Al-Si or Al-Si-Cu as the underlying material in Examples 14 - 23, and an anti-reflective layer was formed thereon in the same manner as in each of the examples (SiC, SiO or an anti-reflective layer comprising an organic or inorganic substance determined by the same method as in Example 23 in a case where Cu was used as the underlying material), thereby performing the resist patterning.

As a result, the standing wave effect was reduced and satisfactory patterning was conducted in the same manner as in each of the previous examples.

Example 34

In this example, the present invention was applied by using SiC as an anti-reflective layer for forming a stable pattern on a Si substrate using KrF excimer lithography.

In the method of forming a resist pattern in this example, as shown in Fig. 40, an anti-reflective layer ARL was formed with silicon carbide on a silicon substrate as the silicic underlying material and a photoresist PR was formed on the anti-reflective layer ARL, thereby forming the resist pattern.

At first, description will be made to the procedures for selecting SiC as the anti-reflective layer and the method of determining the condition to be satisfied by SiC. The following procedures were conducted.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on a Si substrate without an anti-reflective layer, which was exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 41 shows the standing wave effect in this case. As shown in Fig. 41, the standing wave effect was about ± 20%.

(2) In Fig. 41, the maximum value of the standing wave effect situates, for example, at 985 nm of the resist film thickness. Fluctuation for the amount of photoresist absorption in the resist film was determined relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, while taking notice on the resist film thickness of 985 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) The procedure (2) was repeated for each of a plurality of other resist film thicknesses.

(4) The results are shown in the figures and a common region in them was determined. Such a procedure was determined for each of the film thicknesses of the anti-reflective layers, by which an optimum value (n value, k value) for the optical property of a certain film thickness was determined.

The optimum condition for the anti-reflective layer was determined. Based on the result, SiC having n = 2.3 and k = 0.65 was used at a layer thickness of 25 nm as the anti-reflective layer, to greatly reduce the standing wave effect.

Fig. 42 shows a comparison between a case of using SiC at 25 nm as the anti-reflective layer (graph for "with SiC") and a case of not using the anti-reflective layer (graph for "without SiC"). In the case of using SiC at 25 nm, the standing wave effect was reduced to less than ±1%. The standing wave effect in the case of not using SiC was ±23%. Accordingly, the standing wave effect was reduced to less than 1/23 by using SiC as the anti-reflective layer on Si.

Example 35

Also in this example, silicon oxide (SiO) having an optimal condition as the anti-reflective layer was determined by using the same method as in the previous example. That is, in this example, SiO having n = 2.1, k = 0.7 was used at a film thickness of 30 nm as the anti-reflective layer to greatly reduce the standing wave effect.

Fig. 43 shows a comparison between a case of using SiO at 30 nm as the anti-reflective layer (graph for "with SiO") and a case of not using the anti-reflective layer (graph for "without SiO"). In the case of using SiO at 30 nm, the standing wave effect was about ±1%. The standing wave effect in the case of not using SiO was ±23%. Accordingly, the standing wave effect was reduced to less than about 1/23 by using SiC as the anti-reflective layer on Si.

Example 36

In this example, an anti-reflective layer as shown in Fig. 40 was formed by forming a SiC film with n = 2.3 ± 0.2 and k = 0.65 ± 0.2 shown in Example 34 by the following method.

That is, in this example, a film was formed by utilizing a thermal CVD process at a temperature of 100°C to 1500° and usually under a pressure, preferably, from 0.01 to 10,000 Pa, more preferably, 100 to 10,000 Pa by using the following gas as the starting material gas:

$SiCl_4 + C_3H_8 + H_2$,
$SiHCl_3 + C_3H_8 + H_2$,
$SiH_4 + C_3H_8 + H_2$,
$SiH_4 + C_2H_4 + H_2$,
$SiH_4 + C_3H_8 + H_2$,
$SiCl_3 + CH_3 + H_2$,
$SiH_4 + C_3H_8 + H_2$ or
$SiH_4 + C_3H_8 + H_2$.

Thus, a SiC film having an aimed anti-reflective effect could be obtained.

Example 37

In this Example, an SiC film was formed as below to obtain an anti-reflective layer. That is, in this example, a film was formed by utilizing a plasma CVD process and using a photochemical reaction in a gas mixture comprising: $Si_2H_6 + Si(CH_3)H_3 + C_2H_2$.

Example 38

In this example, a SiC film was formed as below to obtain an anti-reflective layer.

A film was formed by an ECR plasma process by utilizing an ECR plasma CVD process using microwave (at 2.45 GHz) from a gas mixture comprising; $SiH_4 + C_2H_4 + H_2$, $SiH_4 + C_2H_4 + H_2$ or $SiH_4 + CH_4 + H_2$.

Example 39

In this example, a SiC film was formed as below to obtain an anti-reflective layer. That is, a film was formed by utilizing a sputtering method using SiC as a target.

Example 40

In this example, an anti-reflective layer was formed by patterning a SiC film by etching.

In this case, the SiC film was etched by a reactive ion etching process using CF_4, CHF_3, C_2F_6, C_3F_8, SF_6 or NF_3 gas as an etchant and adding Ar to improve the ionic property, thereby obtaining an anti-reflective layer of a desired pattern.

Example 41

In this example, a SiO film having $n = 2.1 \pm 0.2$ and $k = 0.7 \pm 0.2$ shown in Example 35 was formed by the following method to form an anti-reflective layer shown in Fig. 40 and described for the function in Fig. 43.

That is, a film was formed by using a gas mixture of $SiH_4 + O_2 + N_2$ at a temperature from normal temperature to 500°C under a pressure of 0.01 Pa - 10 Pa. Thus, an SiO layer having a desired anti-reflective effect was obtained.

Example 42

The SiC layer and the SiO layer in each of the examples described above were formed on the underlying single crystal silicon, underlying polycrystal line silicon and underlying amorphous silicon, respectively, to form anti-reflective layers. As a result, a desired anti-reflective effect could be obtained to attain a satisfactory pattern formation.

Example 43

In this example, the present invention was applied by using SiO_x as an anti-reflective layer for forming a stable pattern on a W-Si film using KrF excimer lithography.

In the method of forming a resist pattern in this example, as shown in Fig. 44, an anti-reflective layer ARL was formed with SiO_x on an underlying W-Si material as refractory metal silicide and a photoresist PR was formed on the anti-reflective layer ARL, thereby forming the resist pattern.

In this example, the present invention is applied by using SiO_x as the anti-reflective layer ARL, particularly, in a case of forming a material layer as a gate with W-Si on a substrate 1 such as a Si semiconductor substrate and patterning the same by a photolithographic step using a photoresist PR and an etching step, thereby obtaining a gate structure.

At first, description will be made to the procedures for selecting SiO_x as the anti-reflective layer to be used on W-Si and the method of determining the condition to be satisfied by SiO_x. The following procedures (1) - (6) were conducted.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on W-Si under without an anti-reflective layer and exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 7 shows the standing wave effect in this case. As shown in Fig. 7, the standing wave effect was about ± 20%.

(2) In Fig. 7, the maximum value of the standing wave effect situates, for example, at 985 nm of the resist film thickness. Fig. 8 shows the equi-contour lines for the amount of absorbed light in the resist film relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, taking notice on the resist film thickness of 985 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) Figs. 9, 10 and 11 show the results of repeating the procedures (2) above to each of the resist film thicknesses of 1,000 nm, 1 017.5 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Fig. 8 to Fig. 11,

$n_{ar1} = 4.9$, $k_{ar1} = 0.1$, or

$n_{ar1} = 2.15$, $k_{ar1} = 0.67$

were obtained.

That is, the condition to be satisfied by the optimum anti-reflective layer with the thickness of the anti-reflective layer being set as 30 nm is:

$n_{ar1} = 4.9$, $k_{ar1} = 0.1$, or

$n_{ar1} = 2.15$, $k_{ar1} = 0.67$.

When the standing wave effect was determined by using the above-mentioned condition, the results shown in Fig. 12 and Fig. 13 were obtained. In each of the cases, the standing wave effect was extremely small and it was about less than 1%. The standing wave effect was reduced to about 1/20 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were conducted in a case of setting the thickness of the anti-reflective layer as 30 nm. When the procedures (2) - (4) were repeated also for anti-reflective layer (ARL thickness) of other different layer thicknesses, an optimum condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer could be determined. Fig. 14 and Fig. 15 show the obtained results.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above are present or not by using a spectroscopic ellipsometer (SOPRA Co.). As a result, it has been found that the optical constant shows changes in Fig. 45 corresponding to the film forming conditions upon forming the SiO_x film by using the CVD process. In Fig. 45, regions shown by open circles satisfy the conditions in Figs. 14 and 15. That is, Fig. 46 shows the standing wave effect in a case of using the SiO_x film at 25 nm thickness as an anti-reflective layer and in a case of not using the anti-reflective layer. In the case of using a SiO_x film at 25 nm, the standing wave effect was about ±1.8% and the standing wave effect was reduced to less than about 1/12 as compared with the case of not using the anti-reflective layer.

Example 44

In this example, a SiO_x film having $n = 2.4 \pm 0.6$ and $k = 0.7 \pm 0.2$ shown in Example 43 was formed by the following method to form an anti-reflective layer as shown in Fig. 46.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process and using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2.

Example 45

In this example, a SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was formed by the following method to form an anti-reflective layer having an anti-reflective function as shown in Fig. 46.

That is, in this example, a film was formed by utilizing a parallel plate type plasma CVD process and using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 and using Ar as a buffer gas.

Example 46

In this example, a SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was formed by the following method to form an anti-reflective layer having an anti-reflective function as shown in Fig. 46.

That is, in this example, a film was formed by utilizing an ECR type plasma CVD process and using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2.

Example 47

In this example, a SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was formed by the following method to form an anti-reflective layer having an anti-reflective function as shown in Fig. 46.

That is, in this example. a film was formed by utilizing a ECR type plasma CVD process and using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 and using Ar as a buffer gas.

Example 48

In this example, a SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was formed by the following method to form an anti-reflective layer having an anti-reflective function as shown in Fig. 46.

That is, in this example, a film was formed by utilizing a bias ECR plasma CVD process and using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2.

Example 49

In this example, a SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was formed by the following method to form an anti-reflective layer having an anti-reflective function as shown in Fig. 46.

That is, in this example, a film was formed by utilizing a bias ECR type plasma CVD process and using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 and using Ar as a buffer gas.

Example 50

In this example, the SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was etched for the underlying material using a resist pattern as a mask by the following method.

That is, the SiO_x film was etched by a reactive etching process using a gas system of CHF_3 (50 - 100 SCCM) + O_2 (3 - 20 SCCM) under a pressure of about 2 Pa and with a power of about 100 to 1000 W, to obtain a desired pattern by etching.

Example 51

In this example, the SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was etched for the underlying material using a resist pattern as a mask by the following method.

That is, the SiO_x film was etched by a reactive etching process using a gas system of C_4F_8 (30 - 70 SCCM) + CHF_3 (10 - 30 SCCM) under a pressure of about 2 Pa and with a power of about 100 to 1000 W, to obtain a desired pattern by etching.

Example 52

In this example, the SiO_x film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 43 was etched for the underlying material using a resist pattern as a mask by the following method.

That is, the SiO_x film was etched by a reactive etching process using a gas system of S_2F_2 (5 - 30 SCCM) under a pressure of about 2 Pa and with a power of about 100 to 1000 W, to obtain a desired pattern by etching.

Example 53

In this example, the present invention was applied by using a $Si_xO_yN_z$ or Si_xN_y film as an anti-reflective layer for forming a stable pattern on a W-Si film by using KrF excimer lithography.

In the method of forming a resist pattern in this example, as shown in Fig. 47, an anti-reflective layer ARL was formed with $Si_xO_yN_z$ or Si_xN_y on the underlying W-Si as a refractory metal silicide and a photoresist PR was formed on the anti-reflective layer ARL, thereby forming the resist pattern.

In this example, the present invention is applied by using $Si_xO_yN_z$ or Si_xN_y as the anti-reflective layer ARL, particularly, in a case of forming a material layer with W-Si as a gate on a substrate 1 such as a Si semiconductor substrate and patterning the same by a photolithographic step using a photoresist PR and an etching step, thereby obtaining a gate structure.

At first, description will be made to the procedures for selecting $Si_xO_yN_z$ or Si_xN_y as the anti-reflective layer to be used on W-Si and the method of determining the condition to be satisfied by $Si_xO_yN_z$ or Si_xN_y. The following procedures (1) - (6) were conducted.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on W-Si without an anti-reflective layer and exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 7 shows the standing wave effect in this case. As shown in Fig. 7, the standing wave effect was about ± 20%.

(2) In Fig. 7, the maximum value of the standing wave effect situates, for example, at 985 nm of the resist film thickness. Fig. 8 shows equi-contour lines for the amount of absorbed light in the resist film relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, taking notice on the resist film thickness of 985 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) Figs. 9, 10 and 11 show the results of repeating the procedures (2) above to each of the resist film thicknesses of 1,000 nm, 1,017.5 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Fig. 8 to Fig. 11,

n_{ar1} = 4.9, k_{ar1} = 0.1, or

n_{ar1} = 2.15, k_{ar1} = 0.67

were obtained.

That is, the condition to be satisfied by the optimal anti-reflective layer with the thickness of the anti-reflective layer being set as 30 nm is:

n_{ar1} = 4.9, k_{ar1} = 0.1, or

n_{ar1} = 2.15, k_{ar1} = 0 67.

When the standing wave effect was determined by using the above-mentioned condition, the results shown in Fig. 12 and Fig. 13 were obtained. In Fig. 12 and Fig. 13, the standing wave effect was extremely small and it was about less than ±1% in each of the cases. The standing wave effect was reduced to about 1/20 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were conducted in a case of setting the thickness of the anti-reflective layer as 30 nm. When the procedures (2) - (4) were repeated also for anti-reflective layer (ARL thickness) of other different layer thicknesses, an optimal condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer could be determined. Fig. 14 and Fig. 15 show the obtained results.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above are present or not by using a spectroscopic ellipsometer (SOPRA Co.).

As a result, it has been found that the optical constant shows changes in Fig. 48 corresponding to the film forming conditions upon forming the $Si_xO_yN_z$ or Si_xN_y film by using the CVD process. In Fig. 48, regions shown by open circles satisfy the conditions in Figs. 14 and 15. That is, Fig. 46 shows the standing wave effect in a case of using the $Si_xO_yN_z$ or Si_xN_yfilm at 25 nm thickness as an anti-reflective layer and in a case of not using the anti-reflective layer. In the case of using the $Si_xO_yN_z$ or Si_xN_y film at 25 nm, the standing wave effect was about ±1.8% and the standing wave effect was reduced to less than about 1/12 as compared with the case of not using the anti-reflective layer.

Example 54

In this example, a $Si_xO_yN_z$ film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, by using a microwave (2.45 GHz), from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O.

Example 55

In this example, a $Si_xO_yN_z$ film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, by using a microwave (2.45 GHz), from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O and using Ar as a buffer gas.

Example 56

In this example, a $Si_xO_yN_z$ film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O.

Example 57

In this example, a $Si_xO_yN_z$ film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O and using Ar as a buffer gas.

Example 58

In this example, a Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, by using a microwave (2.45 GHz), from a gas mixture of SiH_4 + NH_3 or a gas mixture of SiH_2Cl_2 + NH_3.

Example 59

In this example, an Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 or a gas mixture of SiH_2Cl_2 + NH_3 and using Ar as a buffer gas.

Example 60

In this example, an Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, by using a microwave (2.45 GHz), from a gas mixture of SiH_4 + NH_3 or a gas mixture of SiH_2CL_2 + NH_3.

Example 61

In this example, an Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was formed by the following method to form an anti-reflective layer as shown in Fig. 47.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 or a gas mixture of SiH_2Cl_2 + NH_3 by using Ar as a buffer gas.

Example 62

In this example, a $Si_xO_yN_z$ or Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was etched by the following method using a resist pattern as a mask.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by using a gas system of CHF_3 (50 - 100 SCCM) + O_2 (3 - 20 SCCM), under a pressure of about 2 Pa and with a power of about 100 - 1000 V by using a reactive etching process with improved ionic property, thereby etching a desired pattern.

Example 63

In this example, an $Si_xO_yN_z$ or Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was etched by the following method using a resist pattern as a mask.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by using a gas system of C_4F_8 (30 - 70 SCCM) + CHF_3 - (10 - 30 SCCM), under a pressure of about 2 Pa and with a power of about 100 - 1000 V by using a reactive etching process with improved ionic property, thereby etching a desired pattern.

Example 64

In this example, a Si_xN_y film having n = 2.4 ± 0.6 and k = 0.7 ± 0.2 shown in Example 53 was etched by the following method using a resist pattern as a mask.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by using a gas system of S_2F_2 (5 - 30 SCCM), under a pressure of about 2 Pa and with a power of about 100 - 1000 V by using a reactive etching process with improved ionic property, thereby etching a desired pattern.

Example 65

In this example, the present invention was applied by using a $Si_xO_yN_z$ or Si_xN_y film as an anti-reflective layer for forming a stable resist pattern on an underlying Al, Al-Si or Al-Si-Cu material or on a silicon oxide film such as SiO_2 on the underlying material by using KrF excimer lithography.

In the method of forming the resist pattern in this pattern, as shown in Fig. 50, an anti-reflective layer ARL is formed with $Si_xO_yN_z$ or Si_xN_y on the underlying Al, Al-Si or Al-Si-Cu material as a metal wiring material, a photoresist PR was formed on the anti-reflective layer ARL or the photoresist PR was formed on the anti-reflective layer after forming a silicon oxide film such as SiO_2 on the anti-reflective layer to form a resist pattern. In this example, the present invention was applied by using $Si_xO_yN_z$ or Si_xN_y as the anti-reflective

layer ARL, particularly, in a case of obtaining a wiring structure by forming a material layer as wiring with Al, Al-Si or Al-Si-Cu on a substrate such as a Si semiconductor substrate or forming a silicon oxide film such as SiO_2 on the material layer, which was then patterned by a photolithographic step using the photoresist PR and an etching step.

At first, description will be made to the procedures for selecting $Si_xO_yN_z$ or Si_xN_y as the anti-reflective layer to be used on the underlying Al, Al-Si or Al-Si-Cu material and the method of determining the condition to be satisfied by $Si_xO_yN_z$ or Si_xN_y. The following procedures (1) - (6) were conducted.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on an Al, Al-Si or Al-Si-Cu substrate without an anti-reflective layer and exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 20 shows the standing wave effect in this case. As shown in Fig. 20, the standing wave effect was about ± 29.6%.

(2) In Fig. 20, the maximum value of the standing wave effect situates, for example, at 982 nm of the resist film thickness. Fig. 30 shows equi-contour lines for the amount of absorbed light in the resist film relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, taking notice on the resist film thickness of 982 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) Figs. 31, 32 and 33 show the results of repeating the procedures (2) above to each of the resist film thicknesses of 1,000 nm, 1,018 nm and 1,035 nm, respectively.

(4) As a result of determining a common region in Fig. 30 to Fig. 33,

n_{ar1} = 4.8, k_{ar1} = 0.45, or

n_{ar1} = 2.0, k_{ar1} = 0.8

were obtained.

That is, the condition to be satisfied by the optimal anti-reflective layer with the thickness of the anti-reflective layer being set as 30 nm is:

n_{ar1} = 4.8, k_{ar1} = 0.45, or

n_{ar1} = 2.0, k_{ar1} = 0.8.

When the standing wave effect was determined by using the above-mentioned condition, the results shown in Fig. 34 and Fig. 35 were obtained. In Fig. 34 and Fig. 35, the standing wave effect was extremely small and it was about less than ±1% in each of the cases. The standing wave effect was reduced to about 1/60 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were conducted in a case of setting the thickness of the anti-reflective layer as 30 nm. When the procedures (2) - (4) were repeated also for anti-reflective layer (ARL thickness) of other different layer thicknesses, an optimal condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer could be determined. Fig. 14 and Fig. 36 show the obtained results.

(6) It was investigated as to whether the film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above were present or not by using a spectroscopic ellipsometer (SOPRA Co.). As a result, it has been found that the optical constants show the change in Fig. 51 corresponding to the condition upon forming the $Si_xO_yN_z$ or Si_xN_y film by using the CVD process. The region shown by open circles in Fig. 51 satisfy the conditions in Fig. 14 and Fig. 36. That is, Fig. 52 shows the standing wave effect in a case of using the $Si_xO_yN_z$ or Si_xN_y film at a 25 nm thickness as an anti-reflective layer on the underlying Al, Al-Si, Al-Si-Cu material and in a case of not using the anti-reflective layer. In the case of using the $Si_xO_yN_z$ or Si_xN_y film at 25 nm, the standing wave effect was about ±0.5%, and the standing wave effect was reduced to about 1/60 as compared with the case of not using the anti-reflective layer.

Example 66

In this example, an $Si_xO_yN_z$ film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O.

Example 67

In this example, an $Si_xO_yN_z$ film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, using a microwave (2.45 GHz) from a gas mixture of SiH_4 + NO_2 + N_2 or a gas mixture of SiH_4 + N_2O and using Ar as a buffer gas.

Example 68

In this example, an $Si_xO_yN_z$ film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in

Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O.

Example 69

In this example, an $Si_xO_yN_z$ film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and value on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O, using Ar as a buffer gas.

Example 70

In this example, an $Si_xO_yN_z$ film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, using a microwave (2.45 GHz) from a gas mixture of SiH_4 + NH_3 or a gas mixture of SiH_2Cl_2 + NH_3.

Example 71

In this example, an Si_xN_y film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 or a gas mixture of SiH_2Cl_2 + NH_3 using Ar as a buffer gas.

Example 72

In this example, an $Si_xO_yN_z$ film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + NH_3 or a gas mixture of SiH_2Cl_2 + NH_3.

Example 73

In this example, an Si_xN_y film within a range of values on the curve in the graph showing the relation between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer (Fig. 14, Fig. 36) or values on the curve ±0.3 for n and values on the curve ±0.3 for k shown in Example 65 was formed by the method described below to form an anti-reflective layer shown in Fig. 50.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process, from a gas mixture of SiH_4 + O_2 or a gas mixture of SiH_2Cl_2 + NH_3 using Ar as a buffer gas.

Example 74

In this example, a $Si_xO_yN_z$ or Si_xN_y film within a range of values on the curve in the figure (Fig. 14, Fig. 36) showing a relationship between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer or values on the curve ±0.3 for n and values on the curve +_0.3 for k was etched by the following method using the resist pattern as a mask for the underlying material.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by a reactive etching process using a gas system of CHF_3 (50 - 100 SCCM) + O_2 (3 - 20 SCCM) under a pressure of about 2 Pa and with a power of about 100 to 1000 W and improved with the ionic property to etch a desired pattern.

Example 75

In this example, a $Si_xO_yN_z$ or Si_xN_y film within a range of values on the curve in the figure (Fig. 14, Fig. 36) showing a relationship between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer or values on the curve ±0.3 for n and values on the curve +_0.3 for k was etched by the following method using the resist pattern as a mask for the underlying material.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by a reactive etching process using a gas system of C_4F_8 (30 - 70 SCCM) + CHF_3 (10 - 30 SCCM) under a pressure of about 2 Pa and with a power of about 100 to 1000 W and improved with the ionic property to etch a desired pattern.

Example 76

In this example, a $Si_xO_yN_z$ or Si_xN_y film within a range of values on the curve in the figure (Fig. 14, Fig. 36) showing a relationship between the thickness of the anti-reflective layer and the optical property to be satisfied by the optimum anti-reflective layer or values on the curve ±0.3 for n and values on the curve +_0.3 for k was etched by the following method using the resist pattern as a mask for the underlying material.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by a reactive etching process using a gas system of S_2F_2 (5 - 30 SCCM) under a pressure of about 2 Pa and with a power of about 100 to 1000 W and improved with the ionic property to etch a desired pattern.

Example 77

In this example, in a case of forming a stable resist pattern on a silicon substrate such as of single crystal silicon, polycrystalline silicon, amorphous silicon or doped polysilicon and, on a silicon oxide film such as SiO_2 on the underlying material by using a KrF excimer laser, it has been found according to the present invention that use of an organic or inorganic film having n = 1.8 - 2.6 and k = 0.1 - 0.8, particularly, a $Si_xO_yN_z$ or Si_xN_y film at a film thickness of 20 - 150 nm as the anti-reflective layer was desirable.

In a case of using the $Si_xO_yN_z$ or Si_xN_y film as the anti-reflective layer, the film could be formed by various types of CVD processes. Further, $Si_xO_yN_z$ or Si_xN_y could be etched by RIE using CHF_3, C_4F_8, CHF_3, S_2F_2 series gas as an etchant and improved with the ionic property.

That is, in this example, the present invention was applied in a case of using the $Si_xo_yN_z$ or Si_xN_y film as the anti-reflective layer for forming a stable resist pattern on a silicon series substrate such as single crystal silicon and, on a silicon oxide film such as SiO_2, on the above-mentioned substrate by using KrF excimer lithography.

As shown in Fig. 53, in the method of forming a resist pattern in this example, an anti-reflective layer ARL was formed with $Si_xO_yN_z$ or Si_xN_y on a silic substrate such as single crystal silicon, a photoresist PR was formed on the anti-reflective layer ARL, or the photoresist PR was formed after forming the silicon oxide film such as SiO_2 on the anti-reflective layer, thereby forming a resist pattern.

In this example, the present invention was applied, particularly, in a case of forming a silicon oxide film such as SiO_2 on a silicon series substrate such as of single crystal silicon or on the material layer, which was patterned by a photolithographic step using the photoresist PR and a etching step, in which $Si_xO_yN_z$ or Si_xN_y was used as the anti-reflective layer ARL.

At first, description will be made to procedures for selecting an organic or inorganic film, particularly, a $Si_xO_yN_z$ or $Si_x N_y$ film having n = 1.8 - 2.6 and k = 0.1 - 0.8 at a film thickness = 20 - 150 nm as an anti-reflective layer on the silicon series substrate such as of single crystal silicon or on the underlying material, as well as a method of determining the condition to be satisfied therewith. The following procedures (1) - (6) were conducted.

(1) XP 8843 resist (manufactured by Shipley Microelectronics Co.) was coated on a Si series substrate without an anti-reflective layer and exposed by a KrF excimer laser beam at a wave length of 248 nm, followed by development. Fig. 41 shows the standing wave effect in this case. As shown in Fig. 41, the standing wave effect was about ±20%.

(2) In Fig. 2, the maximum value of the standing wave effect situates, for example, at 985 nm of the resist film thickness. Fluctuation for the amount of absorbed light in the resist film was determined relative to the change of optical constants n_{ar1}, k_{ar1} of the anti-reflective layer, taking notice on the resist film thickness of 985 nm, and setting the thickness of the anti-reflective layer to 30 nm.

(3) The procedure (2) was repeated for each of a plurality of resist films of different thicknesses.

(4) The results are shown in the figures and a common region in them was determined. Such a procedure was determined for each kind of the film thicknesses of the anti-reflective layers, by which an optimum value (n value, k value) for the optical property of a certain film thickness was determined. For instance, the optimum condition to be satisfied by the optimum anti-reflective layer in a case of setting the thickness of the anti-reflective layer as 32 nm was:

n_{ar1} = 2.0 k_{ar1} = 0.55.

Further, the optical condition to be satisfied by the optimum anti-reflective layer upon setting the thickness of the anti-reflective layer as 100 nm was:

n_{ar1} = 1.9 k_{ar1} = 0.35.

When the standing wave effect was determined by using the above-mentioned two conditions, results as shown in Figs. 54 and 55 were obtained. In Figs. 54 and 55, the standing wave effect shown at the optimum value was extremely small and it was less than about ±1% in each of the cases. The standing wave effect was reduced to less than about 1/20 as compared with the case of not using the anti-reflective layer.

(5) The procedures (2) - (4) described above were applied to a case of setting the thickness of the anti-reflective layer as 32 nm and 100 nm. When the procedures (2) - (4) were repeated also to other different thicknesses of the anti-reflective layer (ARL layer thickness), an optimum condition for the anti-reflective layer depending on the thickness of the anti-reflective layer could be determined.

(6) It was investigated as to whether film species capable of satisfying the condition to be met by the anti-reflective layer determined in (5) above were present or not by using a spectroscopic ellipsometer (SOPRA Co.). As a result, it has been found that the optical constants show the change in Fig. 56 corresponding to the condition upon forming the $Si_xO_yN_z$ or Si_xN_y film by using the CVD process. The regions shown by open circles in Fig. 56 satisfy the conditions for (4) described above. Figs. 54 and 53 show the results determining the standing wave effect under the condition shown by the open circles in Fig. 5. In each of the cases, the standing wave effect was less than about ±1.0% by using the $Si_xO_yN_z$ or Si_xN_y film as the anti-reflective layer and the standing wave effect was reduced to about 1/20 as compared with the case of not using the anti-reflective layer.

Example 78

In this example, $Si_xO_yN_z$ or Si_xN_y was used as the anti-reflective layer ARL, particularly, in a case of patterning a silicic substrate such as of polycrystalline silicon, amorphous silicon or doped polysilicon, or a silicon oxide film such as SiO_2 on the silicic layer by a photolithographic step using a photoresist PR and an etching step by using the method shown in Example 77.

At first, description will be made to the procedures for selecting an organic or inorganic film having n = 1.8 - 2.6 and k = 0.1 - 0.8 at a film thickness of 20 - 150 nm, in particular, a $Si_xO_yN_z$ or Si_xN_y film as an anti-reflective layer on a silicon series substrate such as of polycrystalline silicon, amorphous silicon or doped polysilicon by using the same method as in Example 77, as well as a method of determining the condition to be satisfied therewith.

(1) The optical condition to be satisfied by the optimum anti-reflective layer with a thickness of the anti-reflective layer, for example, of 33 nm by using the same method as in Example 77 was n_{ar1} = 2.01, k_{ar1} = 0.62. When the standing wave effect was determined by using this condition, the result as shown in Fig. 57 was obtained. The standing effect in Fig. 57 was extremely small and it was about less than ±1% in each of the cases, The standing wave effect was reduced to about 1/20 as compared with the case of

not using the anti-reflective layer.

(2) The foregoing procedures were applied to the case of setting the thickness of the anti-reflective layer to 33 nm. When the above-mentioned procedures were repeated also for other anti-reflective layers of different thicknesses (ARL layer thickness), an optimum condition for the anti-reflective layer in accordance with the thickness of the anti-reflective layer was obtained.

(3) The condition to be satisfied by the anti-reflective layer determined above corresponds to the region shown by open circles in the change of the optical constants corresponding to the condition upon forming the $Si_xO_yN_z$ or Si_xN_y film by using the CVD process (refer to Fig. 56). Fig. 57 shows the standing wave effect in the case of using the Si_xO_y N_z or Si_xN_y film at a thickness of 33 nm as the anti-reflective layer on the silicon series substrate such as of polycrystalline silicon, amorphous silicon and doped polysilicon and in a case of not using the anti-reflective layer. The standing wave effect in a case of setting the thickness of the $Si_xO_yN_z$ or Si_xN_y film to 33 nm was less than about ±1.0% and the standing wave effect was reduced to less than about 1/20 as compared with the case of not using the anti-reflective layer.

Example 79

In this example, the $Si_xO_yN_z$ film shown in Examples 77 and 78 was formed by the following method to form an anti-reflective layer as shown in Example 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process using a microwave (2.45 GHz) for a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O.

Example 80

In this example, the $Si_xO_yN_z$ film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, the film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or bias ECR plasma CVD process at a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O using Ar as a buffer gas.

Example 81

In this example, the $Si_xO_yN_z$ film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or a bias ECR plasma CVD process from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O.

Example 82

In this example, the $Si_xO_yN_z$ film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or a bias ECR plasma CVD process from a gas mixture of SiH_4 + O_2 + N_2 or a gas mixture of SiH_4 + N_2O and using Ar as a buffer gas.

Example 83

In this example, the Si_xN_y film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or a bias ECR plasma CVD process using a microwave (2.45 GHz) from a gas mixture of SiH_4 + NH_3 or a gas mixture of SiH_2Cl_2 + NH_3.

Example 84

In this example, the Si_xN_y film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or a bias ECR plasma CVD process using a microwave (2.45 GHz) from a gas mixture of SiH_4 + O_2 or a gas mixture of SiH_2Cl_2 + NH_3 using Ar as a buffer gas.

Example 85

In this example, the Si_xN_y film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or a bias ECR plasma CVD process from a gas mixture of SiH_4 + NH_3 or a gas mixture of SiH_2Cl_2 + NH_3.

Example 86

In this example, the Si_xN_y film shown in Examples 77 and 78 was formed by the following method to form the anti-reflective layer as shown in Fig. 53.

That is, in this example, a film was formed by utilizing a parallel plate plasma CVD process, ECR plasma CVD process or a bias ECR plasma CVD process from a gas mixture of SiH_4 + O_2 or a gas mixture of SiH_2Cl_2 + NH_3 using Ar as a buffer gas.

Example 87

In this example, the $Si_xO_yN_z$ or Si_xN_y film shown in Examples 77 and 78 was etched as the underlying material using the resist pattern as a mask by the following method.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by a reactive etching process using a gas system of CHF_3 (50 - 100 SCCM) + O_2 (3 - 20 SCCM), under a pressure of about 2 Pa, with a power of about 100 - 1000 W and with the improved ionic property, to obtain a desired pattern by etching.

Example 88

In this example, the $Si_xO_yN_z$ or Si_xN_y film shown in Examples 77 and 78 was etched as the underlying material using the resist pattern as a mask by the following method.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by a reactive etching process using a gas system of C_4F_8 (30 - 70 SCCM) + CHF_3 (10 - 30 SCCM), under a pressure of about 2 Pa, with a power of about 100 - 1000 W and with the improved ionic property, to obtain a desired pattern by etching.

Example 89

In this example, the $Si_xO_yN_z$ or Si_xN_y film shown in Examples 77 and 78 was etched as the underlying material using the resist pattern as a mask by the following method.

That is, the $Si_xO_yN_z$ or Si_xN_y film was etched by a reactive etching process using a gas system of S_2F_2 (5 - 30 SCCM), under a pressure of about 2 Pa, with a power of about 100 - 1000 W and with the improved ionic property, to obtain a desired pattern by etching.

As has been described above, according to the present invention, in a case of forming a resist pattern on an optional underlying material (substrate) by using an optional monochromatic light as an exposure optical source, the condition for an anti-reflective layer used therein can be determined such that a stable resist pattern can be formed satisfactorily even if the resist pattern is fine. Further, according to the present invention, an anti-reflective layer with such a condition can be formed. Furthermore, according to the present invention, a novel anti-reflective layer can be developed to provide a method of forming a resist pattern using such an anti-reflective layer.

Example 90

In this example, a SiOxNy film is formed by using SiH_4 and N_2O mix gas as raw gas. It is recognized that the formed film contains hydrogen.

Referring to Fig. 58 and Fig. 59, Fig. 58 shows relationship between current ratio SiH_4/N_2O and n, k value of the formed film in this example. Fig. 59 shows relationship between current ratio SiH_4/N_2O and atomic ratio of Si, O, N, H (atom %) of the formed film in this example. As is understood through Fig. 59, the formed SiOxNy film contains H, though the contain ratio changes according to current ratio SiH_4/N_2O. It shows the fact that SiOxNyHz film is formed.

Oualitavely speaking, as appeared in IR spectrum of Fig. 60, in any case of various current ratio, there exists not only peaks showing Si-O, or Si-N bond but exists peaks showing N-H, Si-H bond.

It is considered that the existence of such hydrogen makes a contribution to the anti-reflect effect to a certain extent. It is considered that there exists hydrogen in any shape in obtained film, when hydrogen-containing raw gas is used. Especially, in film forming method using plasuama, the existence of such hydrogen is remarkable.

In this example, varioius x. y. z values of SioxNyHz film investigated from the current ratio SiH_4/N_2O based on Fig. 58 which gives most suitable k and n value for i-line and excimer laser are shown in following table 1. In this experimet, WSi as refractry metal silicide, WSi with SiO_2, and Al-1wt%Si as metal material are used as underlying material. And on the above mentioned underlying materials, various thickness of anti-reflective layers are formed on said underlying material using said SiH_4/N_2O mixed gas.

TABLE 1

x. y. z values of SioxNyHz							
No	underlying material	light	thickness of anti-reflective layer (nm)	x	y	z	current ratio of SiH_4/N_2O
1	WSi	i-line	27	0.614	0.227	0.432	1.0
2	WSi (with SiO_2	excimer	30	0.479	0.208	0.375	1.43
3	Al-Si	excimer	24	0.358	0.189	0.358	1.85
4	Al-Si	excimer	70	0.842	0.263	0.526	0.66

Points of current ratio corresponding to the above 1 to 4, there are drawn the lines showing them, in Fig. 59.

According to the present invention, the followings are understood. In case that SiOxNy:Hz is used as an anti-reflective layer for WSi for wavelength 150 to 450 nm, it is preferred that x is 0.03 to 0.80, and y is 0.10 to 0.30. z can be sero, but when hydrogen is contained, it is preferred that z is 0.20 to 0.60.

According to the present invention, the followings are also understood. In case that SiOxNy:Hz is used as an anti-reflective layer for Al-Si for wavelength 150 to 450 nm, it is preferred that x is 0.03 to 0.70, and y is 0.05 to 0. 30. z can be sero, but when hydrogen is contained, it is preferred that z is 0.1 to 0.5.

As shown in Fig. 61, ordinarily used current ratio of SiH_4/N_2O for forming SiOxNy film is 0.2 to 2.0.

Figs. 62 and 63 show simulated anti-reflect effect (effect for decreasing standing wave) when anti-reflective layers obtained in this example are used. Fig. 62 shows the case that WSi with SiO_2 is used as underlying material. Fig. 63 shows the case that Al-Si is used as underlying material. By referring Figs. 62 and 63, it is understood that in the case having anti-reflective layers (with ARL) there diminished most of standing effect, compared with the case having no anti-reflective layers (without ARL).

Fig. 64 shows the measured anti-reflect effect on 0.44 m line and space pattern in real i-line lithography process. By referring Fig. 64, anti-reflect effect in this example is also understood.

Figs. 65 and 66 show simulated anti-reflect effect. Fig. 65 shows the case that WSi is used as underlying material (i-line, absorption ratio). Fig. 66 shows also the case that WSi is used as underlying material (i-line, reflective ratio). An anti-reflective layer of 30 nm with n, k, value described in the Figures is formed, and deta are measured by using photoresist with n, k, value described in the Figures. Superior anti-reflective effect is obtained in both case of absorption ratio and reflective ratio.

Figs. 67 and 68 show the relationship between thickness of photoresist and critical dimension. The experiment is operated using WSi as underlying material, and KrF excimer laser. Fig. 67 shows the case that data are measured concerning 0.30 m line and space pattern. Fig. 68 shows the case that data are measured concerning 0.35 m line and space pattern. In both cases, chemical amplifying posi resist is used.

Example 91

As aforementioned, the material n value of which is about 2.4 and k value of which is about 0.7 is suitable as an anti-reflective layer for excimer laser on, for example, refractory metal silicide. And also as aforementioned, SiOx, SINx, or SiOxNy is effective such an anti-reflecive layer as described above. It is considered that SiOx, SiNx, or SiOxNy with the n value and k value as described above which is effective for anti-reflectivity can be formed by controlling the n value and k value by controlling the element ratio x and y. It is , however, difficult to obtain a film with desired n value and k value by controlling the ratio by suitable means.

In this example, in order to obtain a film with desired n value and k value, the anti-reflective layer is formed by using as raw gas containing at least silicon element and oxide element. For example, in order to control the element ratio x of SiOx, by using gas current ratio as parameter, it is possible to make x smaller through using higher ratio of raw gas containing silicon element. As a result, the atomic ratio can be controlled, and the optical constant (n, k) can be controlled.

In this example, SiH_4, is used as raw gas containing at least silicon element, and N_2O is used as raw gas containing at least oxide element. The film with desired anti-reflective effect can be formed by controlling the optical constant through using current ratio of SiH_4 and N_2O as parameter. Fig. 58 shows the change of the optical constant of the formed film when the current ratio of SiH_4 and N_2O in parallel electrodetype plasuma CVD camber is changed. The suitable example of film forming conditions for excimer lithography are as follows.

SiH_4 = 50sccm
N_2O = 50sccm
RF power = 190W
pressure = 332.5Pa (2.5torr)
temperature of the substrate = 400 C
distance between electrodes = 1cm

In the above mentioned means, current ratio of raw gas is mainly used as to control optical constant, however, pressure of film forming atmospere, RF power, or temperature of the substrate can be used to control optical constant as parameter.

Example 92

In this example, an anti-reflective layer is formed by using at least one kind of organic compounds containing at least silicon element as raw material. As a result of using an organic compound, coverage of an anti-reflective layer on step improves. Namely, a difference between thickness of an anti-reflective layer on even portion and that of perpendicular portion of step in this example is small, and uniformity of anti-reflective effect in semiconductor device tip improves.

In this example, as an organic compound which has improved step coverage is used, this example can be said it is especally effective for device with severe unevenness. As an organic compound, for example, TEOS, OMCTS ($Si_4O(CH_3)_8$;Si/Uratio = 1), HMDS ($Si_2O(CH_3)_8$;Si/Oratio = 2) and so on can be used. In this example, used conditions for forming film in parallel electrode plasuma CVD chamber are as follows.

OMCTS = 50sccm
RF power = 190W
pressure = 332.5Pa (2.5torr)
temperature of the substrate = 400° C
distance between electrodes = 1 cm

Example 93

When Si content of desired film is larger than the above example 92, SiH_4, which is Si source gas without containing O, N, can be added. In this case, the example of conditions for forming film in parallel electrode plasuma CVD chamber are as follows.

OMCTS = 50sccm
SiH_4 = 5sccm
RF power = 190W
pressure = 332.50Pa (2.5torr)

temperature of the substrate = 400 ° C

Claims

1. In a method of forming a resist pattern by forming an anti-reflective layer on an underlying metalic material and forming a photoresist on said anti-reflective layer, thereby forming a resist pattern, wherein the anti-reflective layer is formed by an organic or inorgaic substance under the conditions of the film thickness and the optimum refractive indices determined by the following means, which comprises:
   (I) determining an equi-contour line for the amount of photoresist absorption to a photoresist of an optionally determined film thickness using the optical condition for the anti-reflective layer as a parameter,
   (II) determining equi-contour lines for the amount of photoresist absorption for a plurality of resist film thicknesses in the same manner as in (I) above,
   (III) finding a common region for the amount of the photoresist absorption for each of the equi-contour lines obtained in (II) above and setting the optical condition defined by the common region as an optimum optical condition for the anti-reflective layer in the condition defined initially in (I) above,
   (IV) determining the optical condition for the anti-reflective layer by conducting the same procedures as described above while changing the condition for the anti-reflective layer and
   (V) finding the optimum optical condition for the anti-reflective layer in a condition for the anti-reflective layer according to (IV) above,
   wherein an anti-reflective layer is formed on an underlying metalic material by using an organic or inorganic substance having a value within ±0.6 for the reflection refractive index n and a value within ± for the absorption refractive index k wherein the reflection refractive index n and the absorption refractive index k are determined according to (V) above, and forming a photoresist on said anti-reflective layer, thereby forming the resist pattern.

2. A method of forming a resist pattern, where in an SiO_x film having reflection refractive index n = 2.4 ± 0.6 and absorptive refractive index k = 0.7 ± 0.2 is used as an anti-reflective layer on an underlying metalic material.

3. A method of forming a resist pattern as defined in claim 2, wherein the thickness of the anti-reflective layer is 30 ± 10 nm.

4. A method of forming a resist pattern, wherein a $Si_xO_yN_z$ film or a Si_xN_y film having reflection refractive index n = 2.4 ± 0.6 and absorption refractive index k = 0.7 ± 0.2 is used as an anti-reflective layer on the underlying metalic material.

5. A method of forming a resist pattern, as defined in clams 1, wherein the underlying metalic material comprises a refractory metal silicide.

6. A method of forming a resist pattern as defined in claims 2, wherein the underlying metalic material comprises a refractory metal silicide.

7. A method of forming a resist pattern as defined in claims 3, wherein the underlying metalic material comprises a refractory metal silicide.

8. A method of forming a resist pattern as defined in claim 4, wherein the underlying metal material comprises a refractory metal silicide.

9. A method of forming a resist pattern, in which a $Si_xO_yN_z$ film is formed as an anti-refrective layer on the underlying metalic material thereby forming a resist pattern.

10. A method of forming a resist pattern as defined in claim 9, weherein the metalic material is anyone of an aluminum and aluminum alloys.

11. A method of forming a resist pattern in which a $Si_xO_yN_z$ or Si_xN_y film as an anti-reflective layer is formed on an underlying silicic series material, thereby forming a resist pattern.

12. A method of forming a resist pattern, as defined in claim 11, weherein the silicic material comprises any one of single crystal silicon, polycrystalline silicon, amorphous silicon and doped poly-silicon.

13. A method of forming a resist pattern as defined in claim 4, wherein the thickness of the anti-reflective layer is less than 60 nm.

14. A method of forming a resist pattern as defined in claim 5, where in the thickness of the anti-reflective layer is less than 60 nm.

15. A method of forming a resist pattern as defined in claim 6, where in the thickness of the anti-reflective layer is less than 60 nm.

16. A method of forming a resist pattern as defined in claim 7, wherein the thickness of the anti-reflective layer is less than 60 nm.

17. A method of forming a resist pattern as defined in claim 8, wherein the thickness of the anti-reflective layer is less than 60 nm.

18. A method of forming a resist pattern as defined in claim 9, where in the thickness of the anti-reflective layer is less than 60 nm.

19. A method of forming a resist pattern as defined in claim 10, wherein the thickness of the anti-reflective layer is less than 60 nm.

20. A method of forming a resist pattern as defined in claim 11, wherein the thickness of the anti-reflective layer is less than 60 nm.

21. A method of forming a resist pattern as defined in claim 12, wherein the thickness of the anti-reflective layer is less than 60 nm.

22. A method of forming a resist pattern in which an anti-reflective layer is formed by anyone of silicon oxide nitride containig hydrogen, silicon oxide containing hydrogen, silicon nitride containing hydrogen, or silicon carbide containing hydrogen, and at least one resist layer is formed on the anti-reflevtive layer.

23. A method of forming resist pattern, wherein $SiO_xN_yH_z$ film, in which x is 0.30 to 0.80, y is 0.10 to 0.30, z is 0 to 0.60, is formed as an anti-reflective layer on underlying refractory metal silicide for exposure wavelengths from 150 to 450 nm, and at least one resist layer is formed on the anti-reflevtive layer.

24. A method of forming resist pattern, wherein $SiO_xN_yH_z$ film, in which x is 0.30 to 0.80, y is 0.10 to 0.30, z is 0,20 to 0. 60, is formed as an anti-reflective layer on underlying refractory metal silicide for exposure wavelengths from 150 to 450 nm, and at least one resist layer is formed on the anti-reflevtive layer.

25. A method of forming a resist pattern, as defined in claim 23, wherein the refractotry metal silicide is lingsten silicide.

26. A method of forming a resist pattern, as defined in claim 24, wherein the high melting point metal silicide is tungsten silicide.

27. A method of forming resist pattern, wherein $SiO_xN_yH_z$ film, in which x is 0.30 to 0.70, y is 0.05 to 0.30, z is 0 to 0.50, is formed as an anti-reflective layer on underlying metalic material for exposure wavelengths from 150 to 450 nm, and at least one photoresist layer is formed on the anti-reflevtive layer.

28. A method of forming a resist pattern, wherein $SiO_xN_yH_z$ film, in which x is 0.30 to 0.70, y is 0.05 to 0.30, z is 0,1 to 0.50, is formed as an anti-reflective layer on underlying metalic material for exposure wave lengths from 150 to 450 nm and at least one resist layer is formed on the anti-reflevtive layer.

29. A method of forming resist pattern as defined in claims 27, wherein the metalic material is anyone of an aluminum and aluminum alloys.

30. A method of forming a resist pattern as defined in claim 28, wherein the metalic material is anyone of an aluminum and aluminum alloys.

31. A method of forming a resist pattern as defined in claim 29, wherein the metalic material is aluminum-silicon alloys.

32. A method of forming a resist pattern as defined in claim 30, wherein the metalic material is an aluminum-silicon alloys.

33. A method of forming film by vapor phase deposition using as a raw gas containing at least silicon element and oxide element, wherein the ratio of silicon element to oxide element is as follows.

$0.4 \leq [Si]/[O] \leq 3$

34. A method of forming film as defined in claims 32, weherein the gas contains a material having at least hydrogen elemnt.

35. A method of forming film by vapor phase deposition using SiH_4 and N_2O as raw gas wherein the gas ratio of said SiH_4 and N_2O is as follows.

$0.4 \leq [SiH_4]/[N_2O] \leq 3$

FIG.1

Method of determining optimum condition

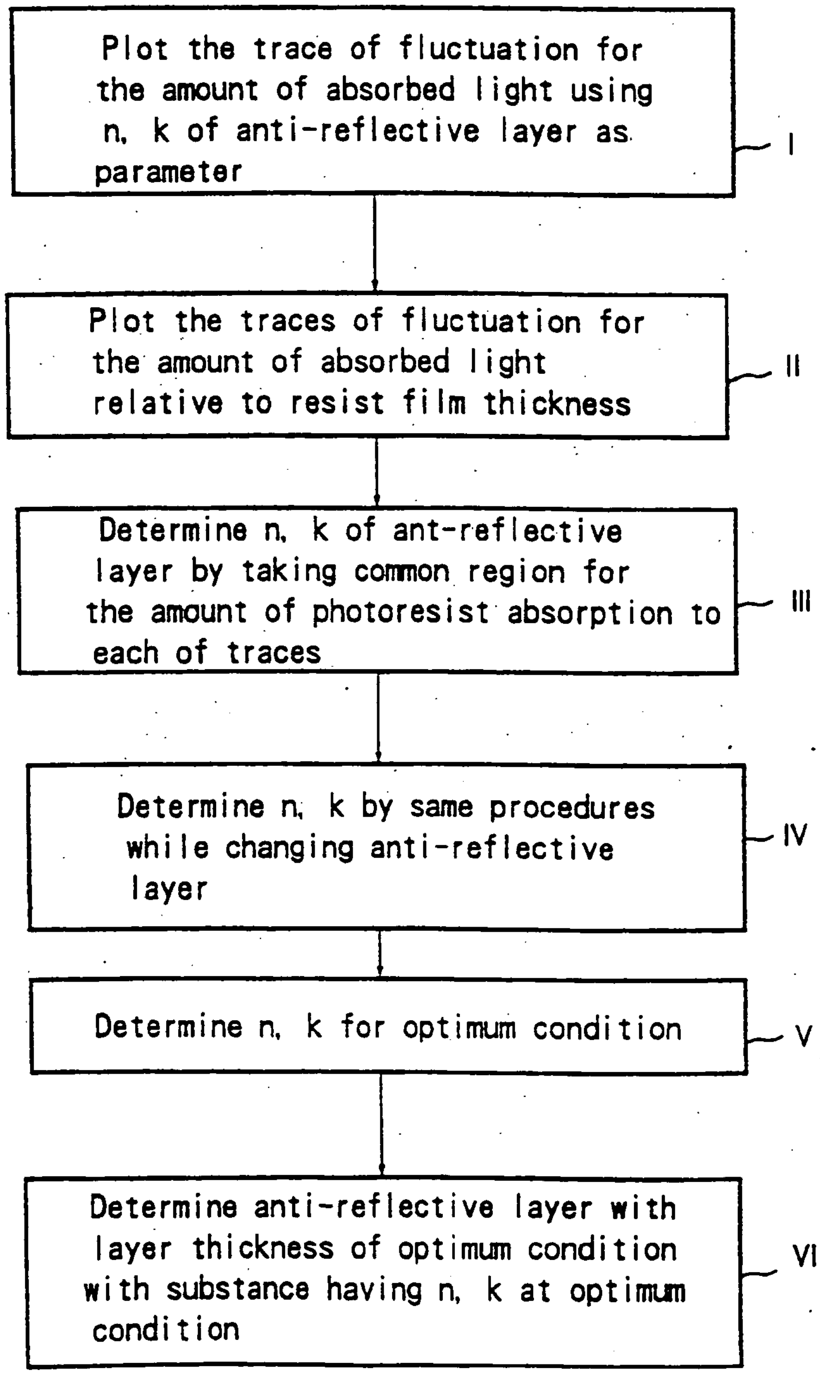
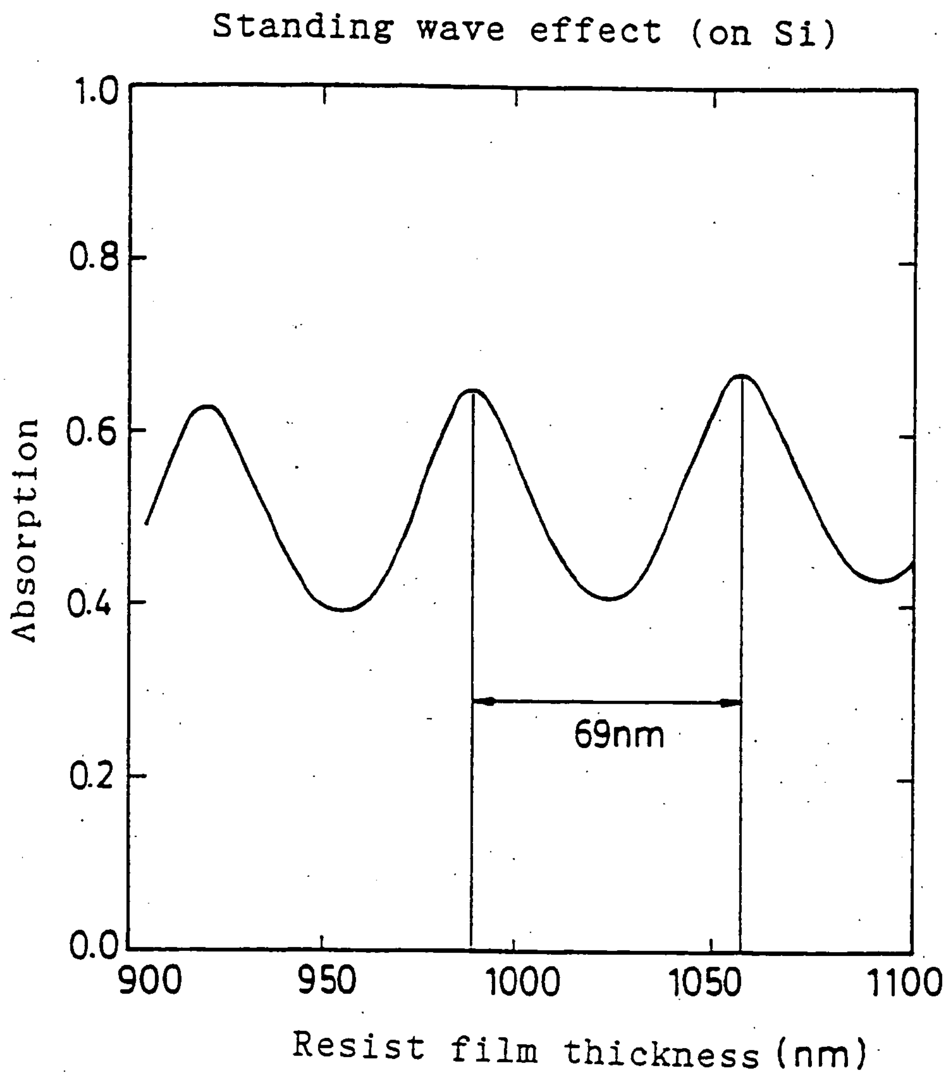


Fig.2



Condition

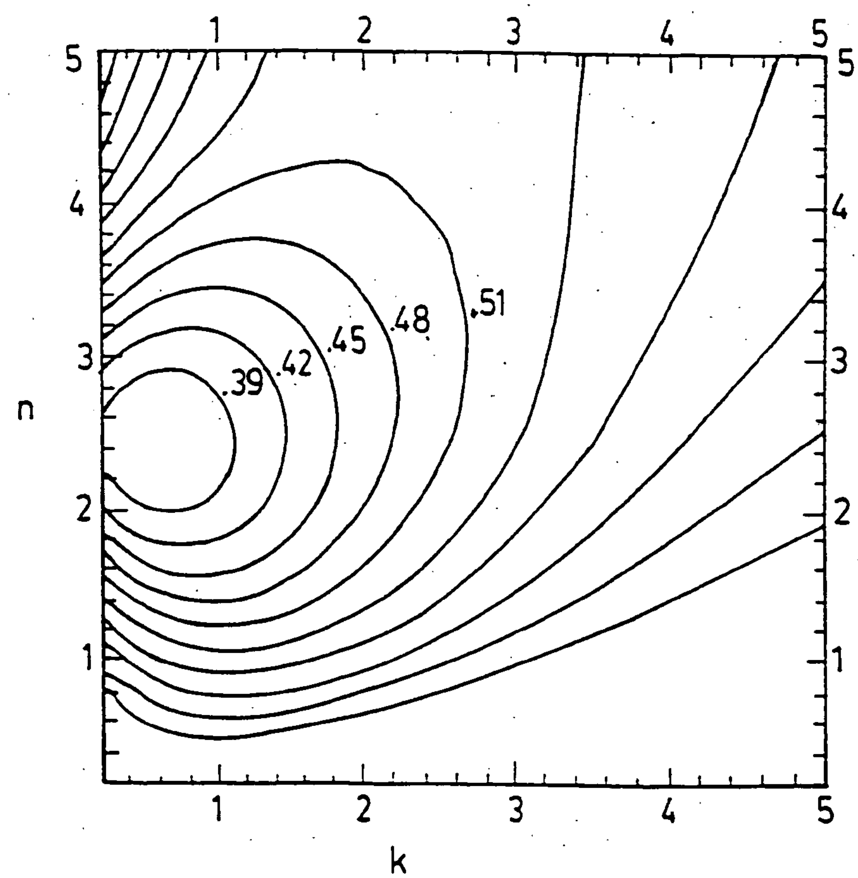
Resist: XP8843 (n=1.802, k=0.0107)

Substrate : Si (n=1.572, k=3.583)

$\frac{\lambda}{2n}$ 68.8 nm in which n=1.802, λ=248nm

Fig.3

Trace of fluctuation for the amount of absorbed light in a resist film when n_{ar1}, k_{ar1} are changed while fixing thickness of anti-reflective layer ARL for a certain resist film thickness

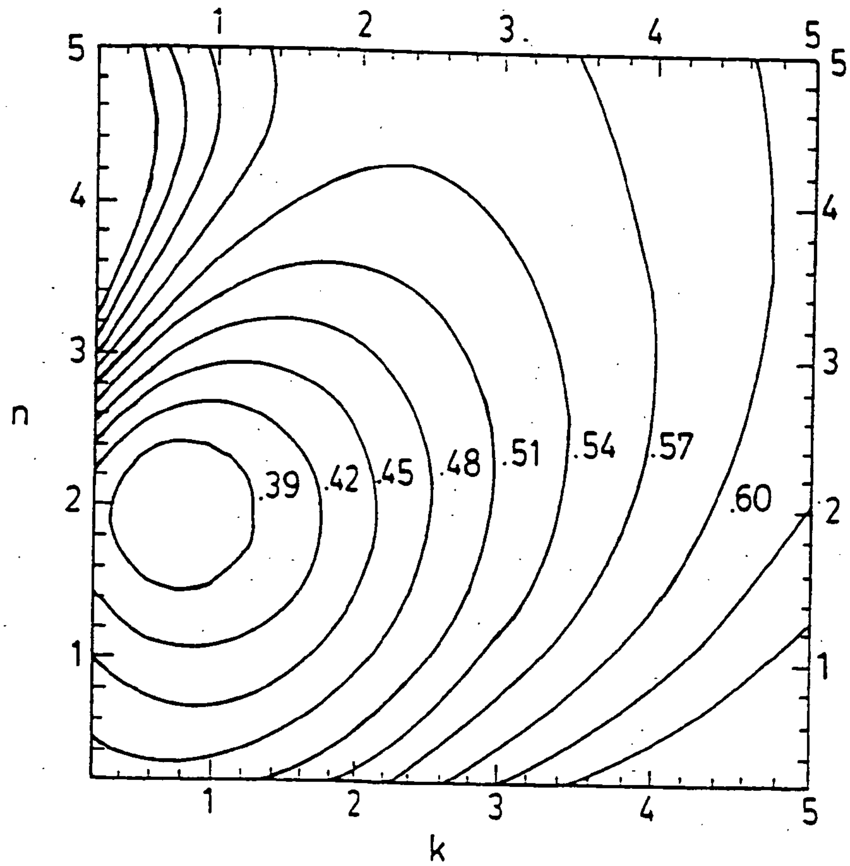


Resist film thickness: 985nm

Anti-reflective layer thickness: 20nm

Fig. 4

Trace for other resist film of different thickness

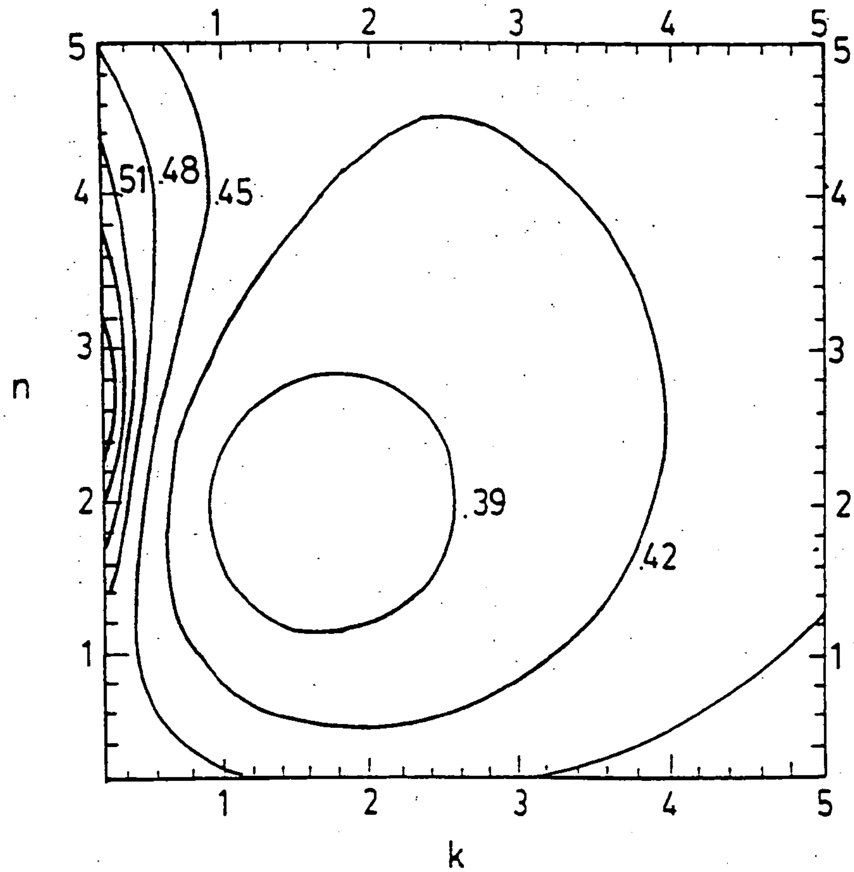


Resist film thickness: 1000nm

Anti-reflective layer thickness: 20nm

Fig.5

Trace for other resist film of different thickness

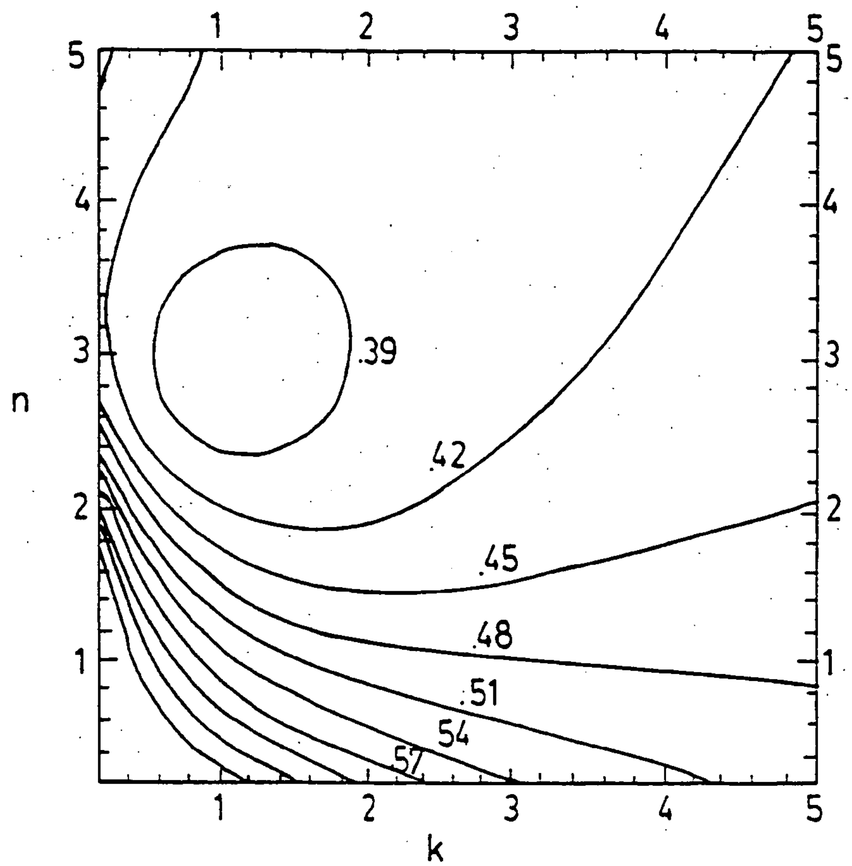


Resist film thickness: 1018nm

Anti-reflective layer thickness: 20nm

Fig.6

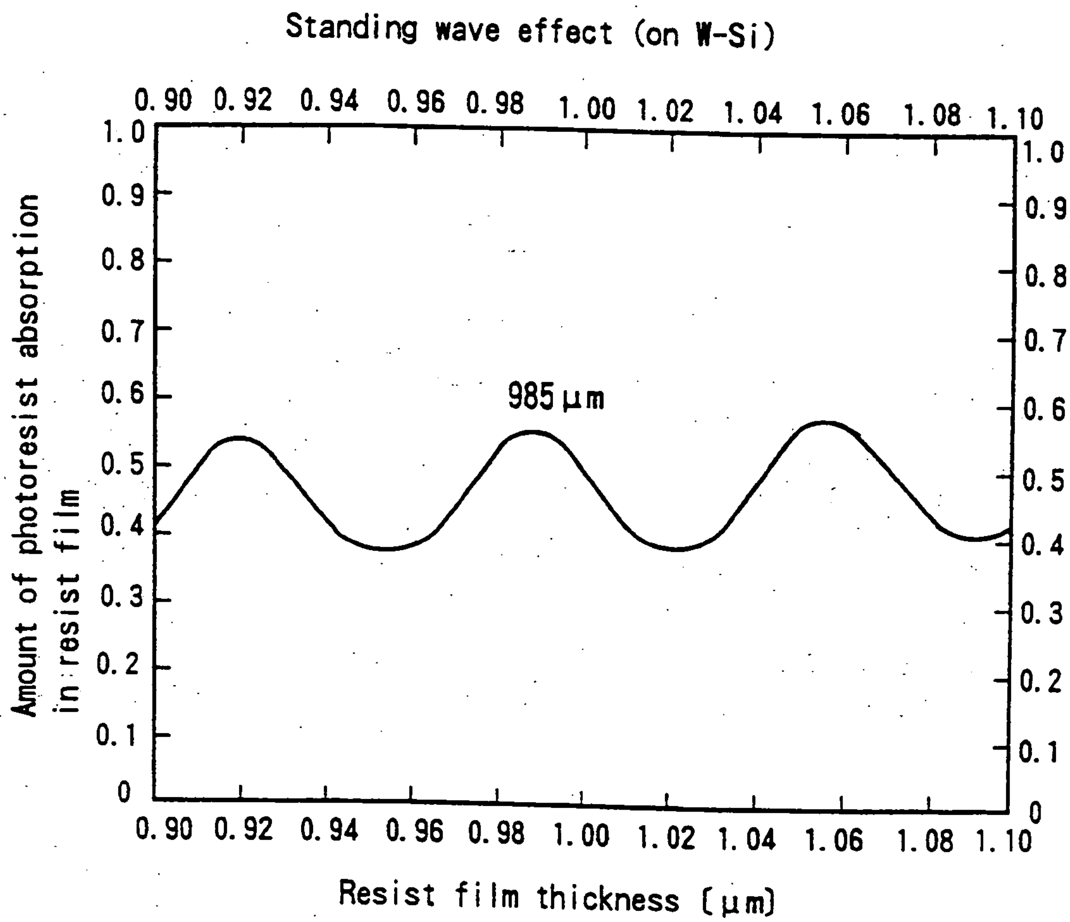
Trace for other resist film of different thickness



Resist film thickness: 1035nm

Anti-reflective layer thickness: 20nm

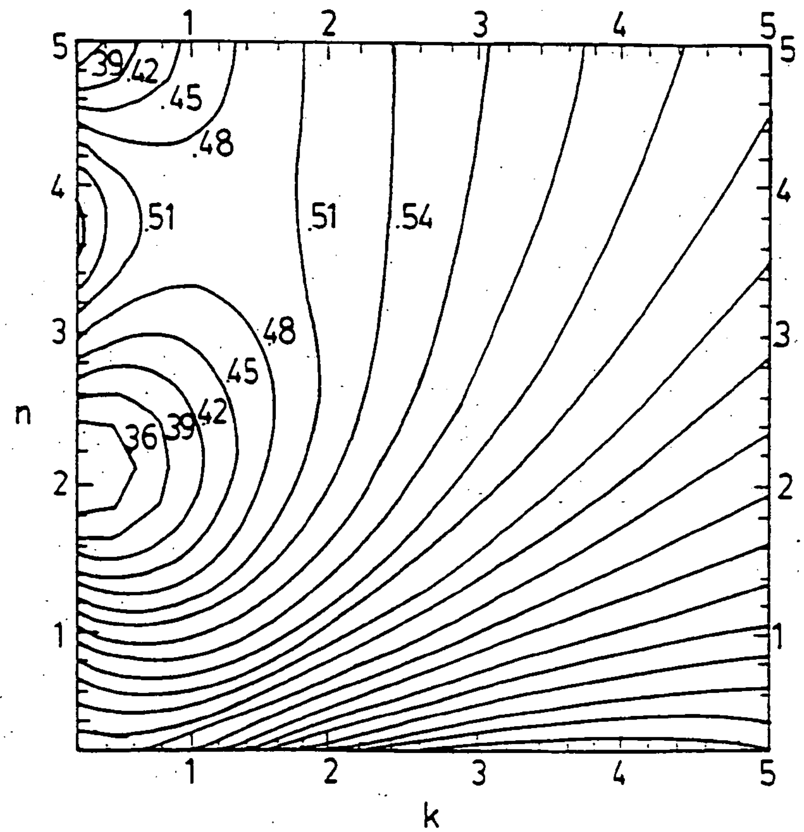
FIG.7



λ=248nm,
XP8843onW-Si,
n_{PR}=1.802, k_{PR}=0.0107,
n_{sub}=1.96, k_{sub}=2.69

Fig.8

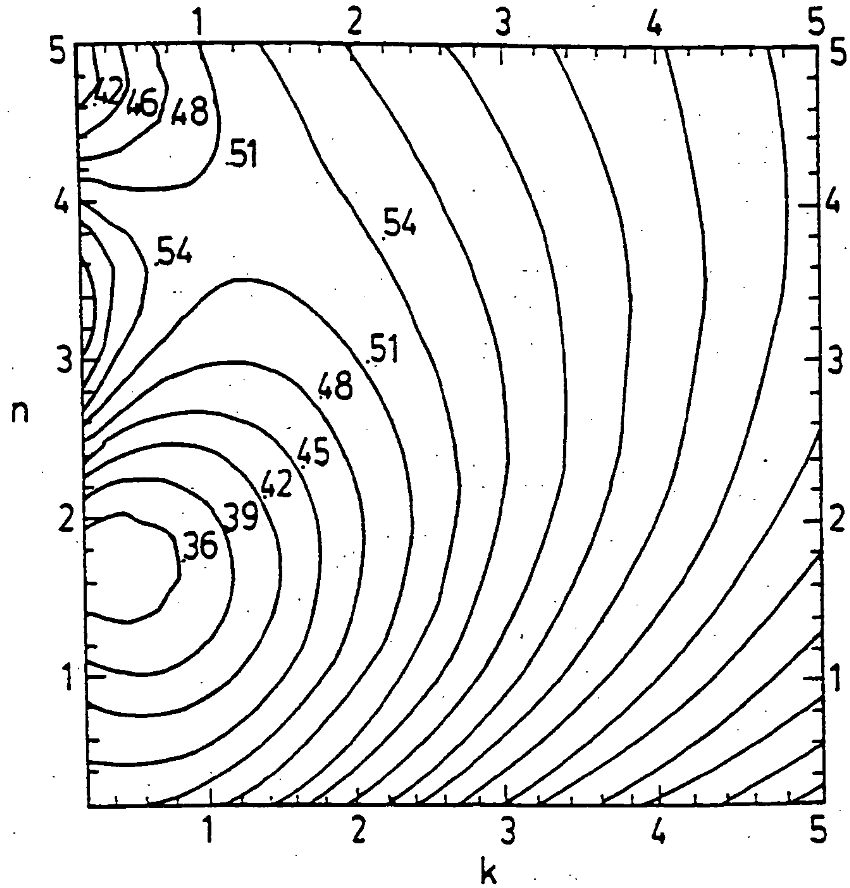
Trace of fluctuation for the amount of absorbed light in resist film relative to the change of n_{arl}, k_{arl} for resist film thickness of 985 nm in a case of anti- reflective layer at 30 nm thickness



$\lambda = 248 nm$
XP8843/ARL/W-Si
$n_{PR} = 1.802$, $k_{PR} = 0.0107$, $d_{PR} = 0.985 \mu m$
n_{arl}, k_{arl} : parameter, $d_{arl} = 0.03 \mu m$
$n_{sub} = 1.96$, $k_{sub} = 2.69$

Fig.9

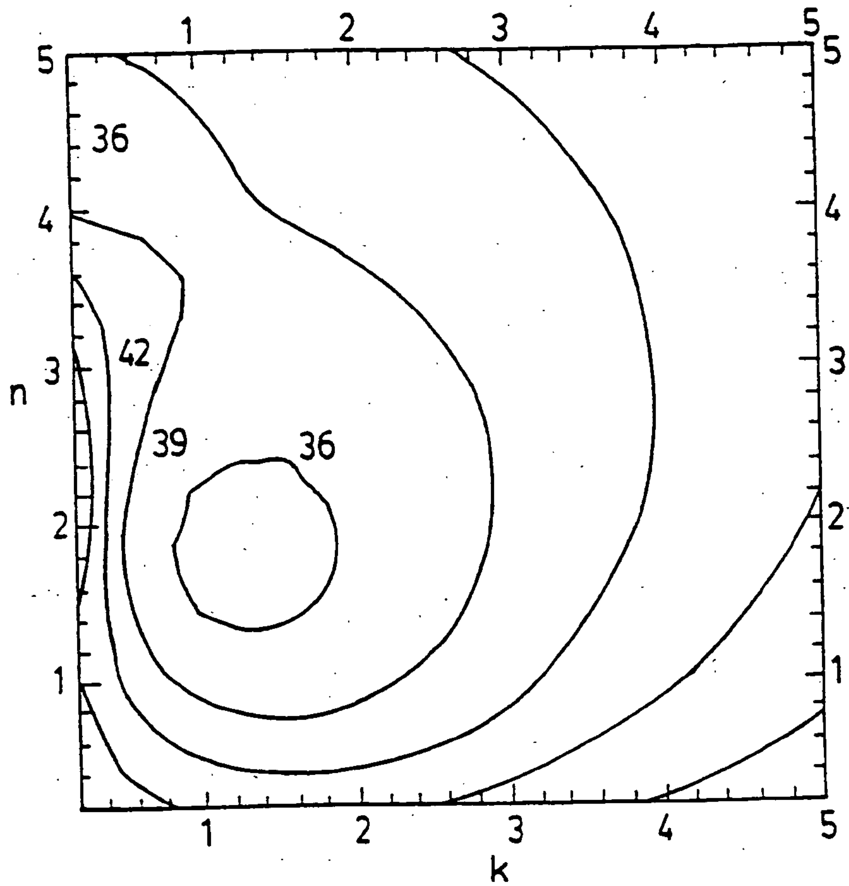
Trace for the resist film thickness of 1000 nm



$\lambda = 248$ nm
XP8843 / ARL / W-Si
$n_{PR} = 1.802$, $k_{PR} = 0.0107$, $d_{PR} = 1.0$ µm
n_{arl} , k_{arl} : parameter , $d_{arl} = 0.03$ µm
$n_{sub} = 1.96$, $k_{sub} = 2.69$

Fig.10

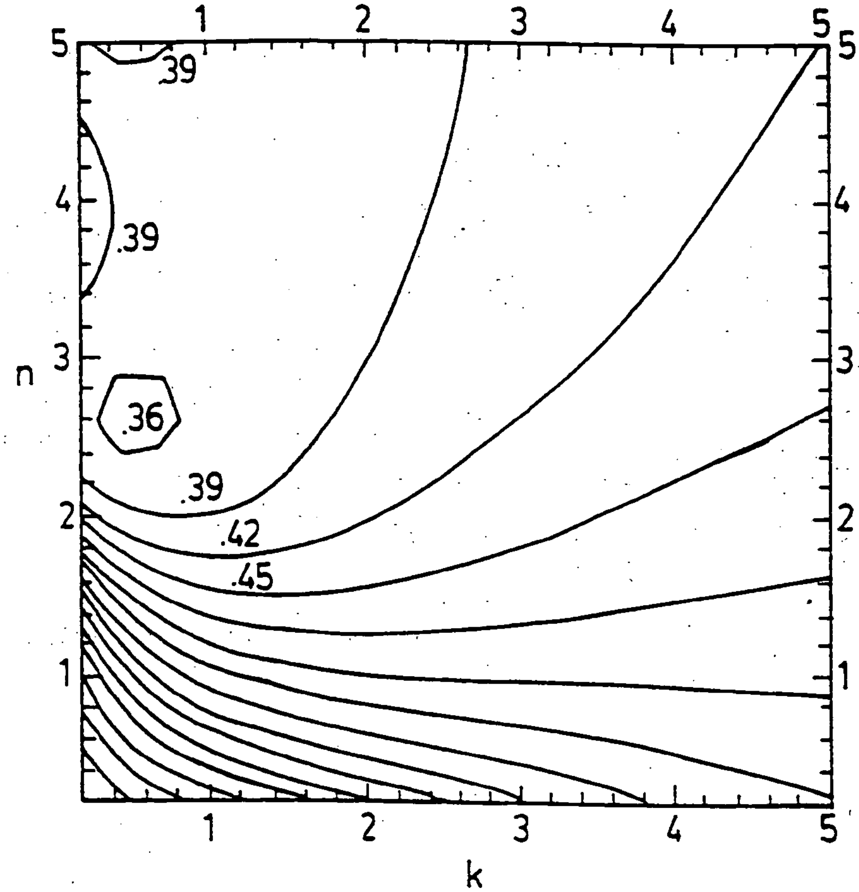
Trace for the resist film thickness of 1017.5 nm



$\lambda = 248\,nm$
XP8843 / ARL / W-Si
$n_{PR} = 1.802$, $k_{PR} = 0.0107$, $d_{PR} = 1.0175\,\mu m$
n_{arl} , k_{arl} : parameter , $d_{arl} = 0.03\,\mu m$
$n_{sub} = 1.96$, $k_{sub} = 2.69$

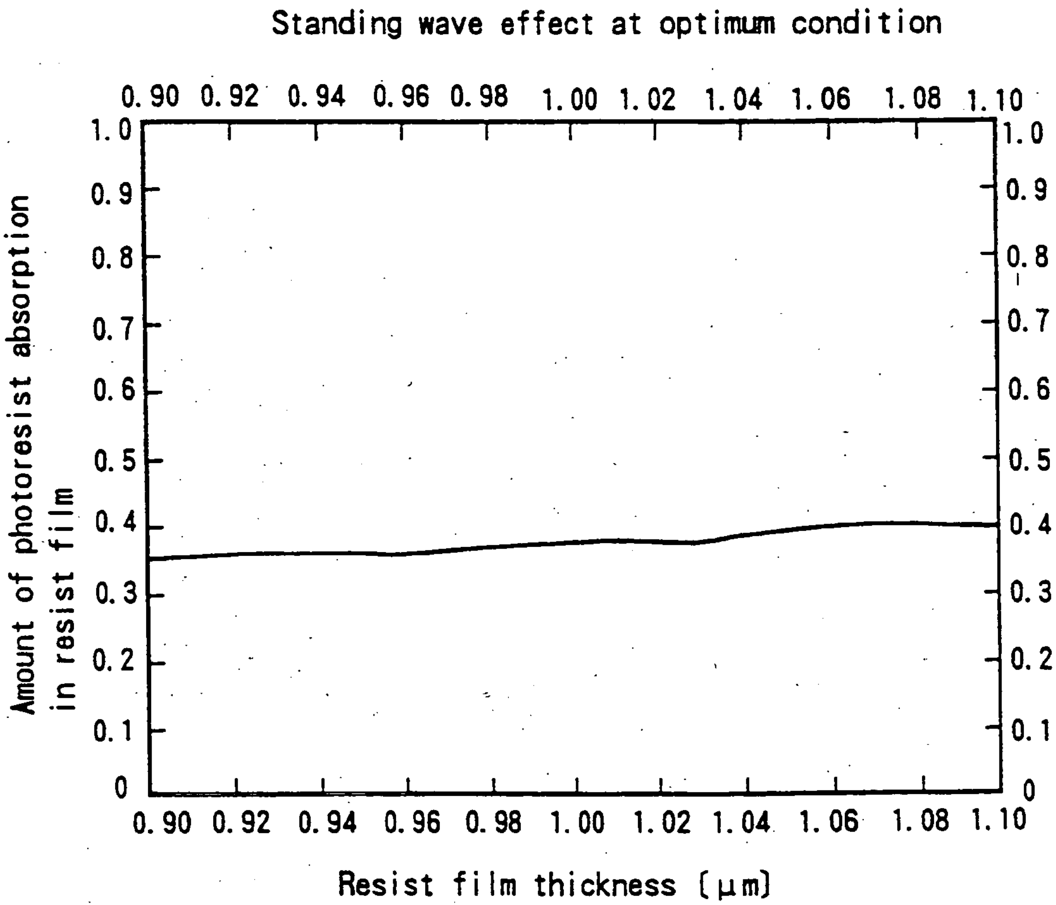
Fig.11

Trace for the resist film thickness of 1035 nm



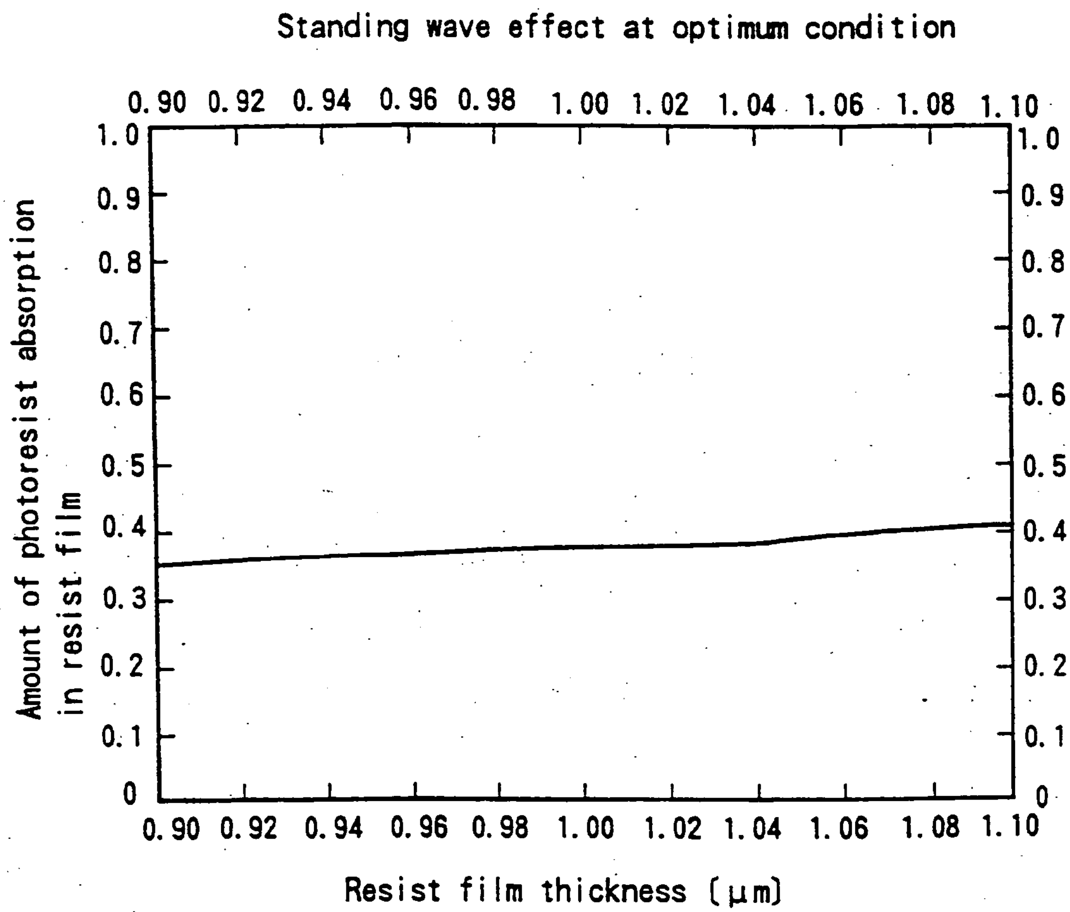
λ = 248 nm
XP8843 / ARL / W-Si
n_{PR} = 1.802 , k_{PR} = 0.0107 , d_{PR} = 1.035 μm
n_{arl} , k_{arl} : parameter , d_{arl} = 0.03 μm
n_{sub} = 1.96 , k_{sub} = 2.69

FIG.12



λ=248nm,
XP8843/ARL/W-Si,
n_{PR}=1.802, k_{PR}=0.0107,
n_{arl}=2.15, k_{arl}=0.67, d_{arl}=0.03 μm,
n_{sub}=1.96, k_{sub}=2.69

FIG.13



λ=248nm,
XP8843/ARL/W-Si,
n_{PR}=1.802, k_{PR}=0.0107,
n_{arl}=4.9 k_{arl}=0.1, d_{arl}=0.03μm,
n_{sub}=1.96, k_{sub}=2.69

FIG.14

Relation between layer thickness and n of anti-reflective layer

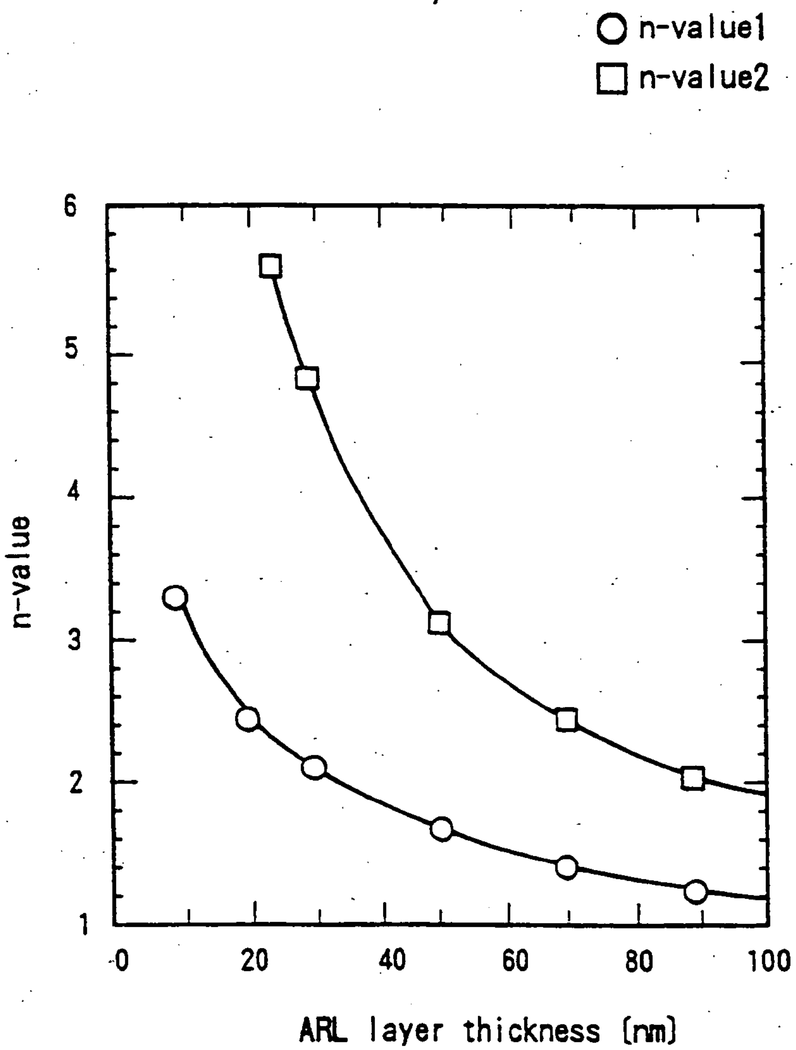


FIG.15

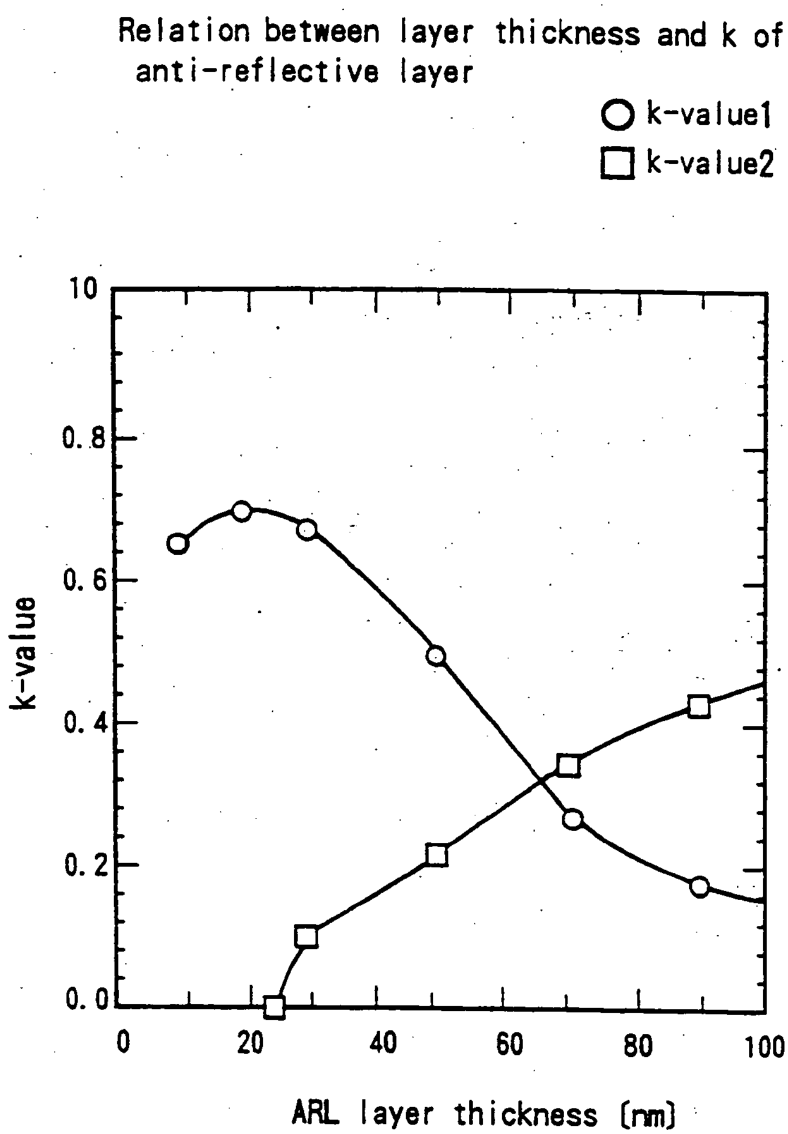

Relation between layer thickness and k of anti-reflective layer
k-value1
k-value2
10
0.8
0.6
0.4
0.2
0.0
k-value
0
20
40
60
80
100
ARL layer thickness (nm)

Fig.16

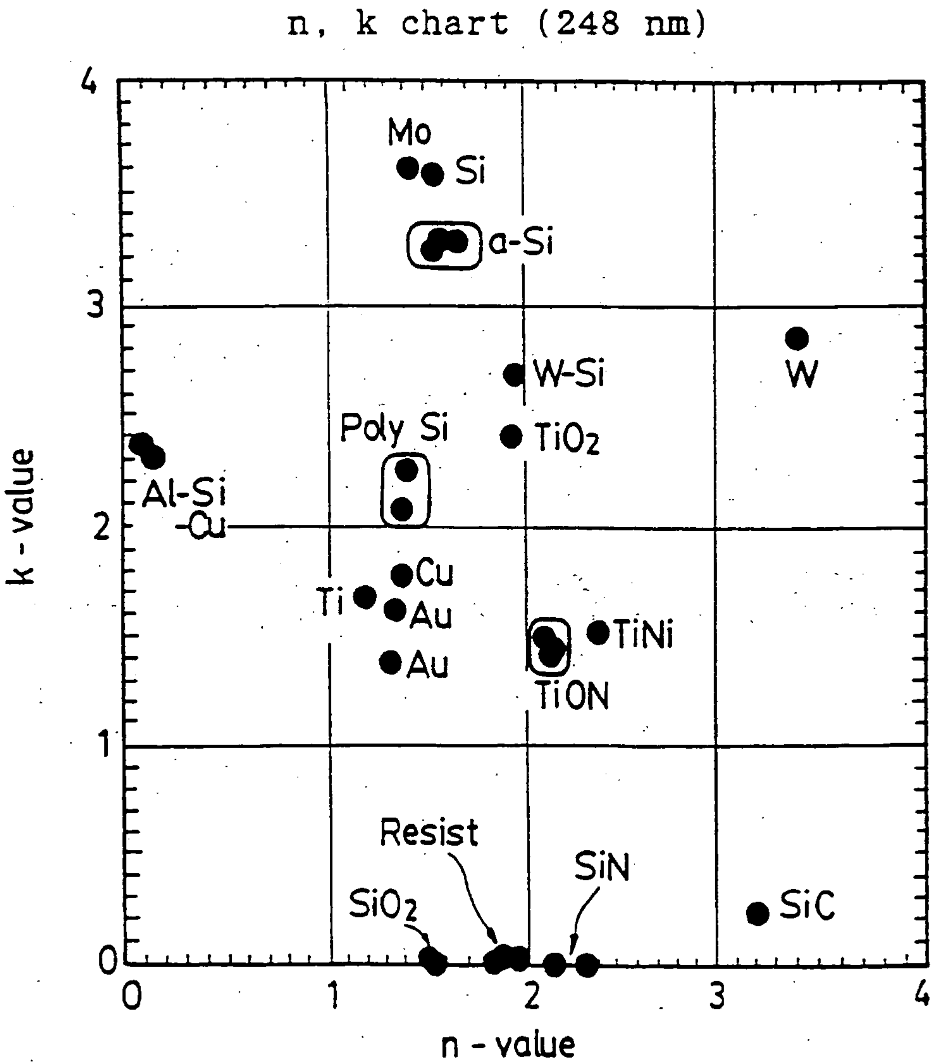
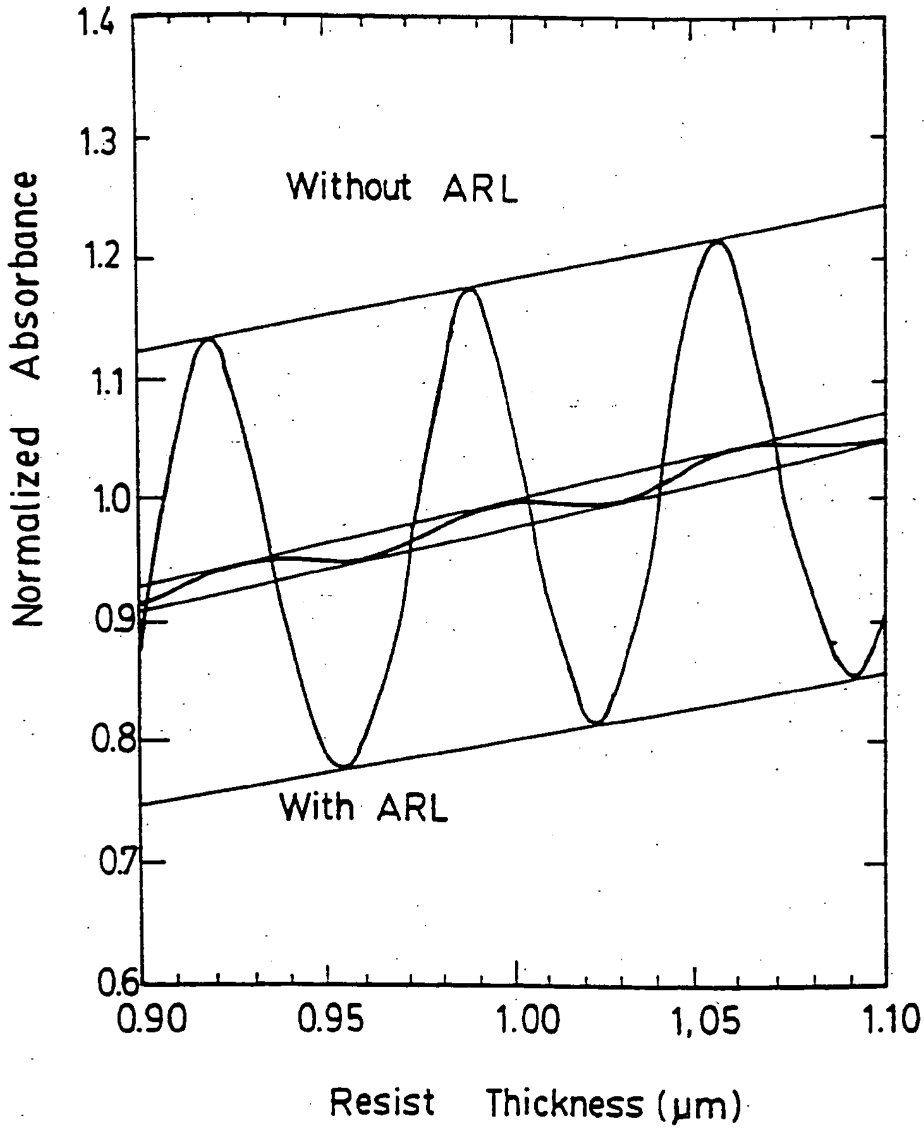

n, k chart (248 nm)
k - value
n - value
4
3
2
1
0
0
1
2
3
4
Mo
Si
a-Si
W-Si
W
TiO2
Poly Si
Al-Si
-Cu
Cu
Ti
Au
Au
TiNi
TiON
Resist
SiN
SiO2
SiC

Fig.17

Anti-reflective effect of SiC (50 nm) on W-Si



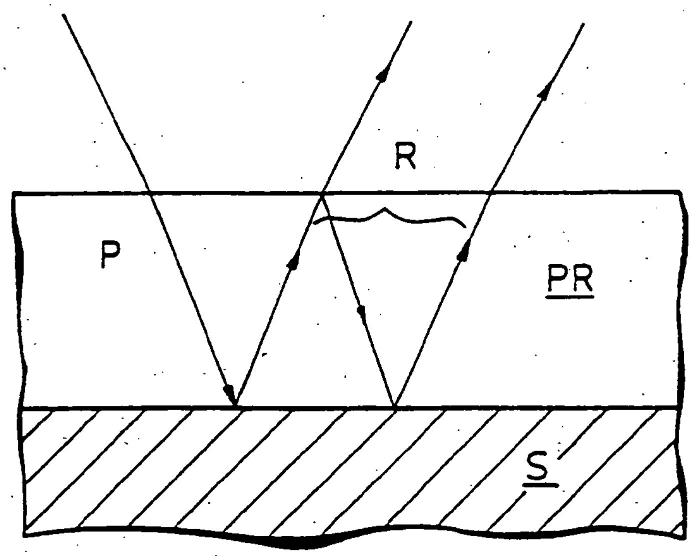
Condition

Photoresist: XP88431μm

Substrate: W-Si

Fig.18

Light interference in resist film



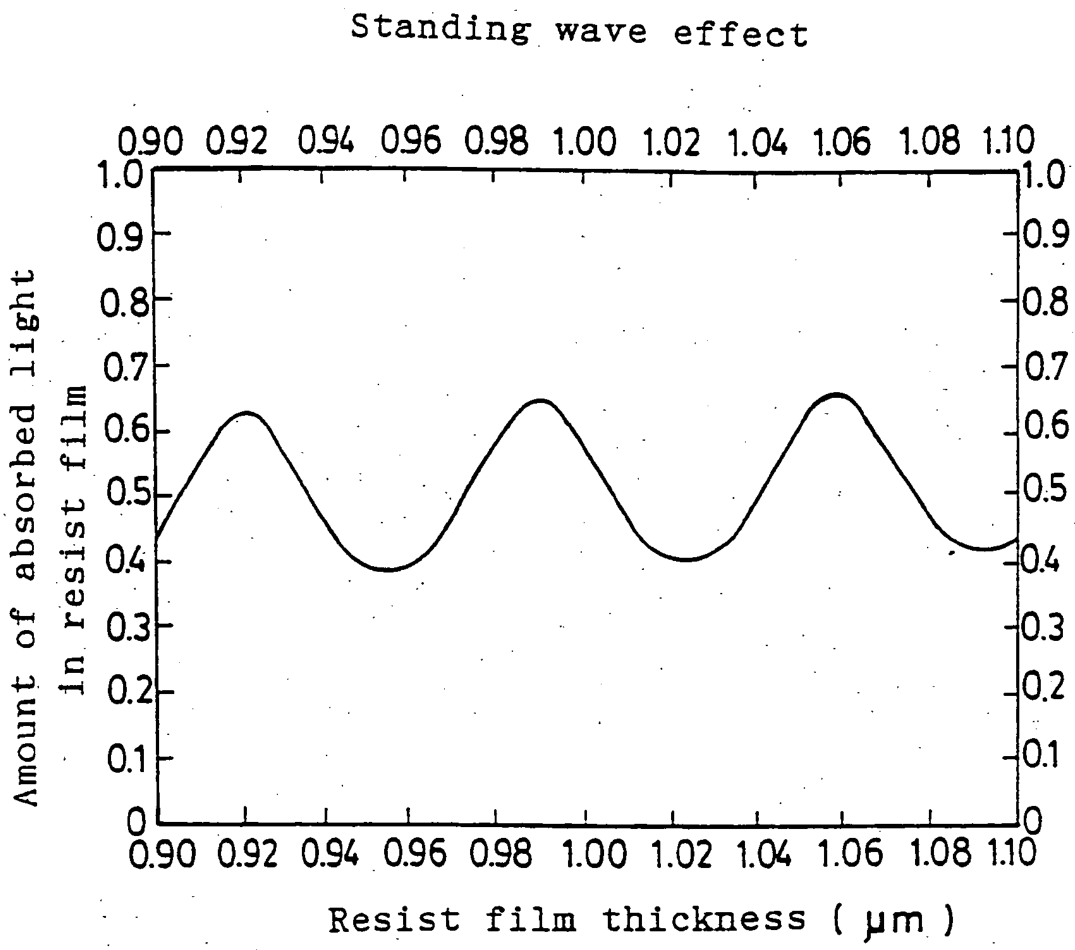
P: Incident light

R: Reflection light

PR: resist

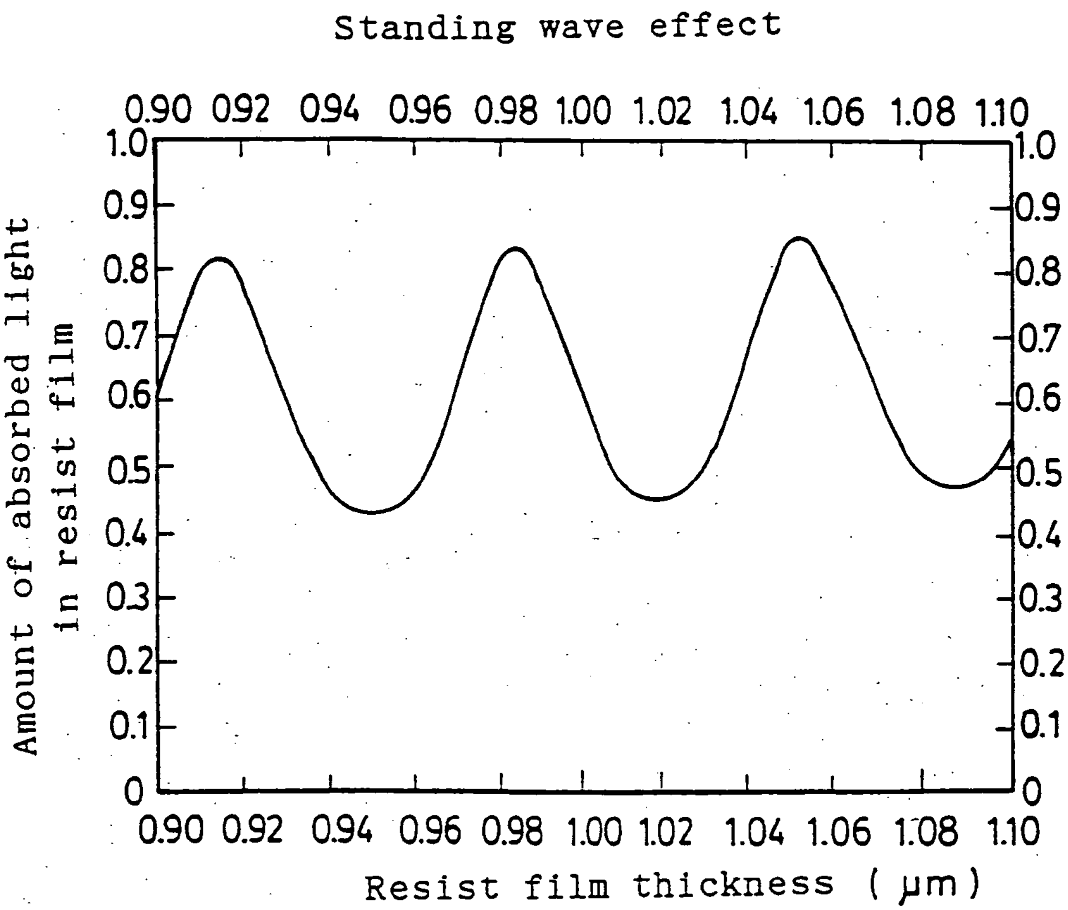
S: substrate

Fig.19



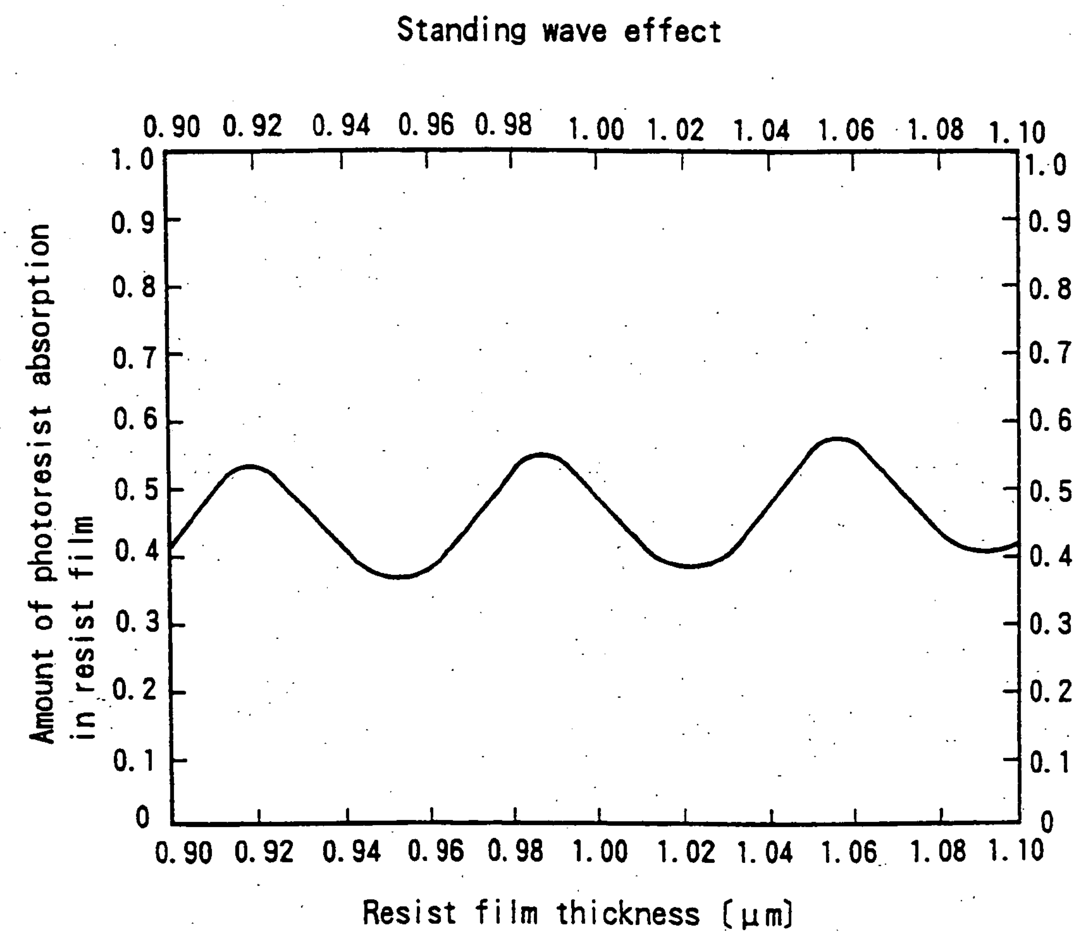
$\lambda = 248\,nm$
XP8843 / Si
$n_{PR} = 1.802$, $k_{PR} = 0.0107$
$n_{Si} = 1.5717$, $k_{Si} = 3.583$

Fig.20



$\lambda = 248\,nm$
XP8843 / A1-Si
$n_{PR} = 1.802$, $k_{PR} = 0.0107$
$n_{sub} = 0.089$, $k_{sub} = 2.354$

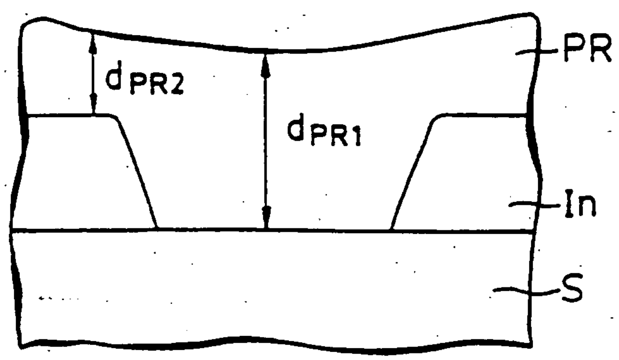
FIG.21



λ=248nm,
XP8843/ARL/W-Si,
n_{PR}=1.802, k_{PR}=0.0107,
n_{sub}=1.96, k_{sub}=2.69

Fig.22

Influence of step



$d_{PR1} \fallingdotseq d_{PR2}$

S: Substrate

In: For example, poly-Si

PR: Resist

Fig.23

Influence of standing wave effect

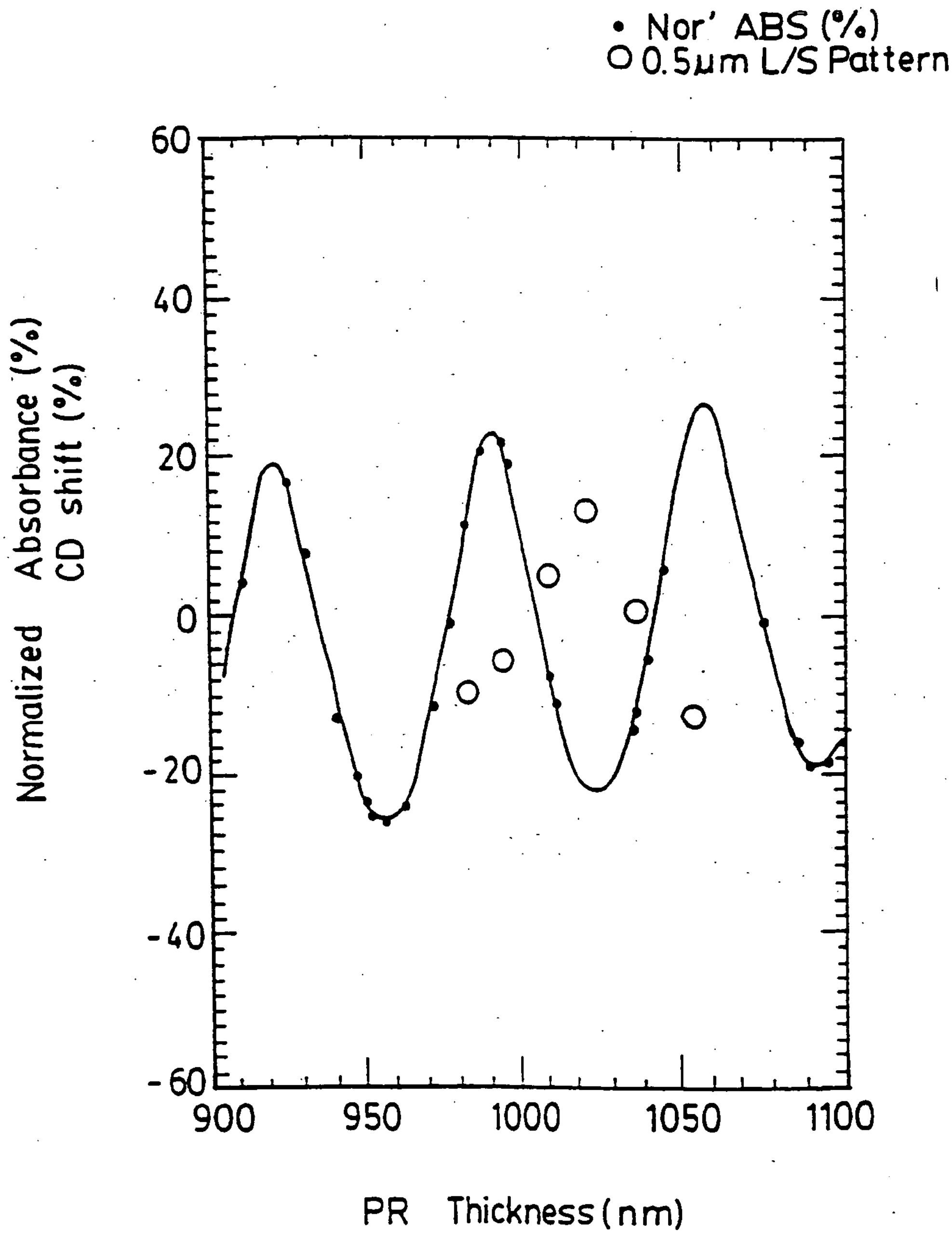


Fig.24

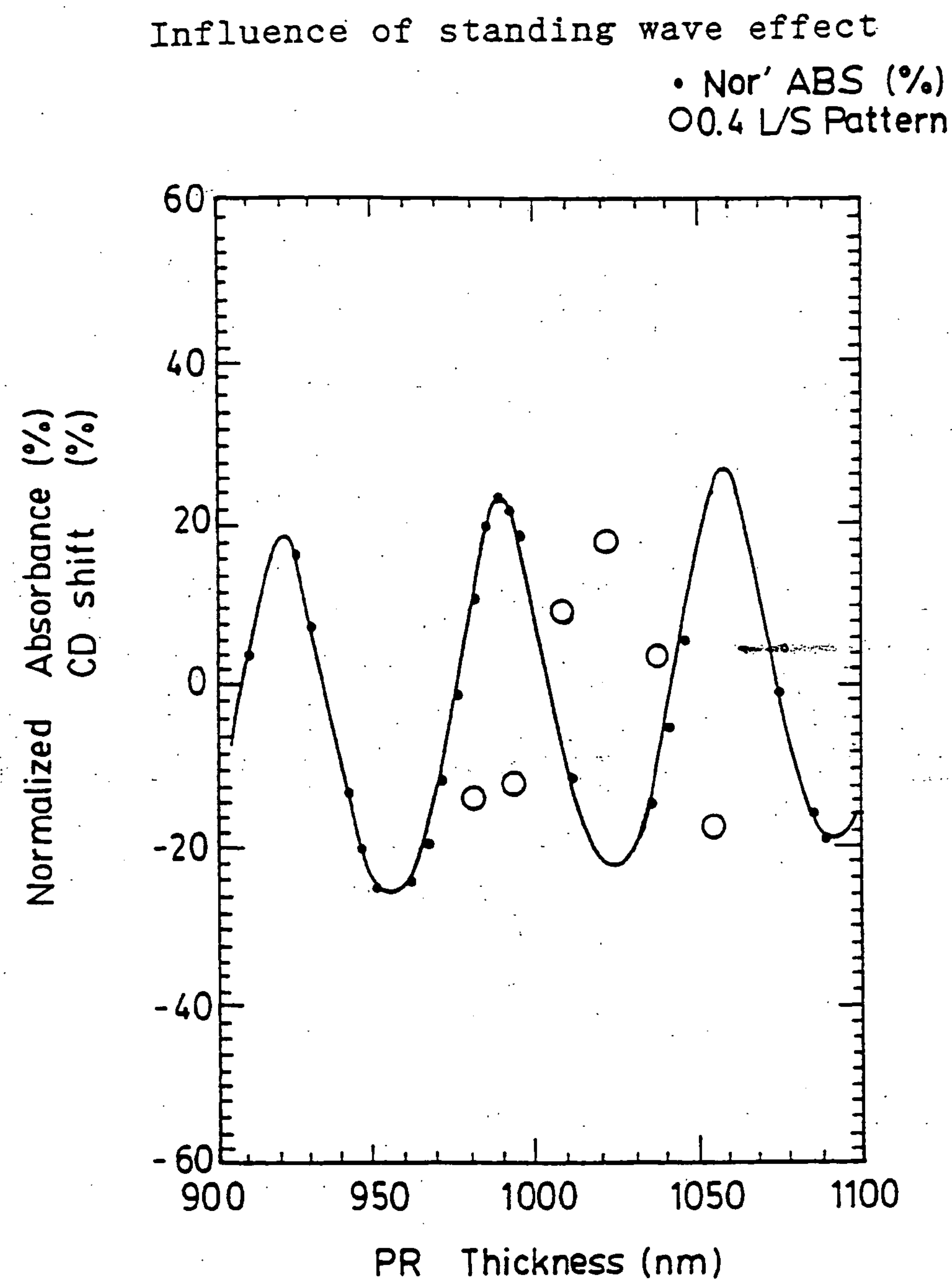

Influence of standing wave effect
• Nor' ABS (%)
○0.4 L/S Pattern
Normalized Absorbance (%)
CD shift (%)
60
40
20
0
-20
-40
-60
900
950
1000
1050
1100
PR Thickness (nm)

Fig.25

Influence of standing wave effect

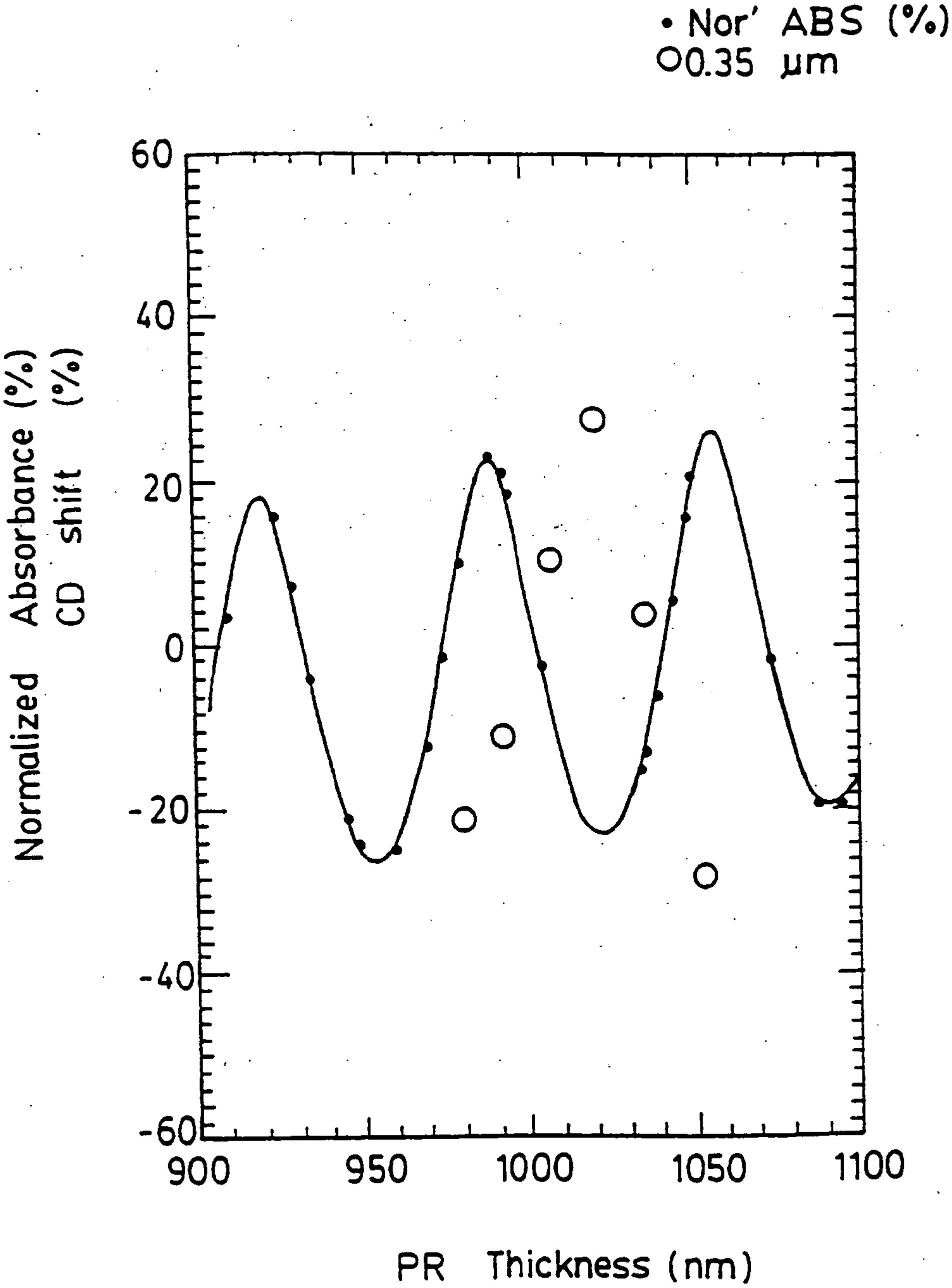


FIG.26

Relation between fluctuation for the amount of photoresist absorption and dimensional change of pattern

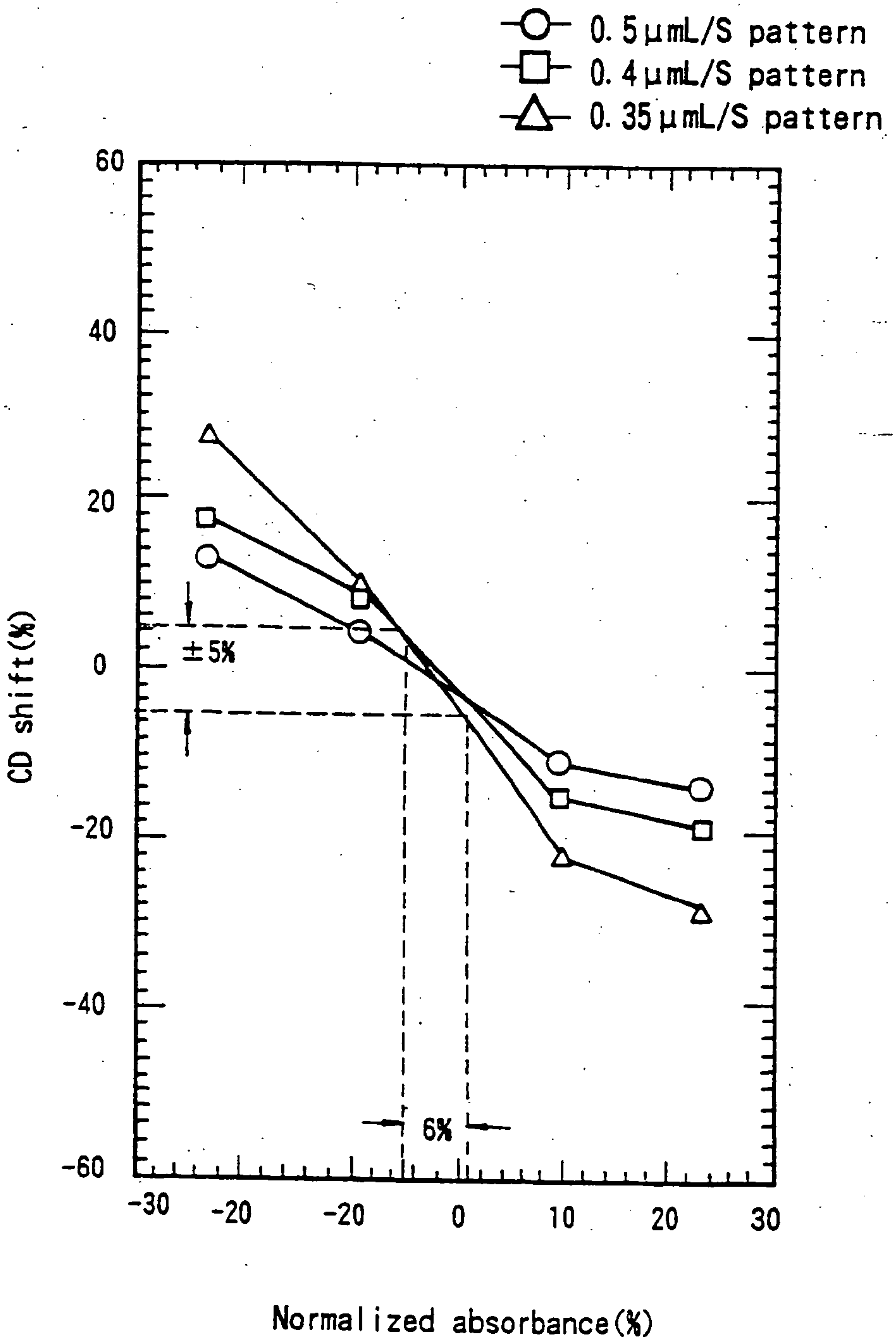
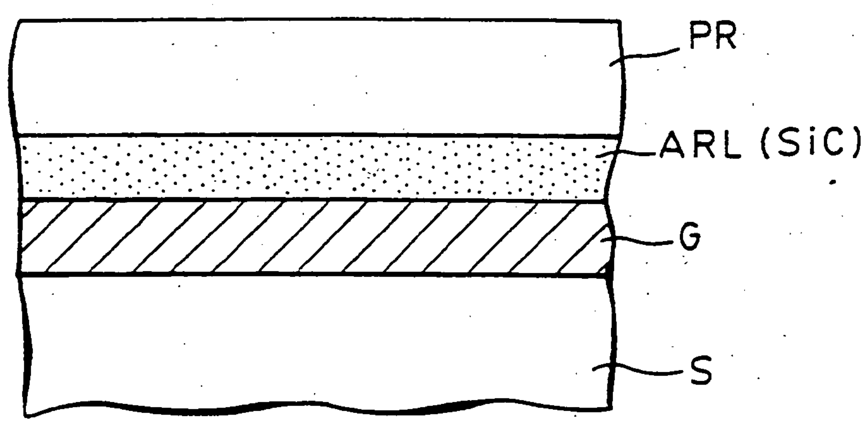


Fig.27

Structure of example



PR: photoresist

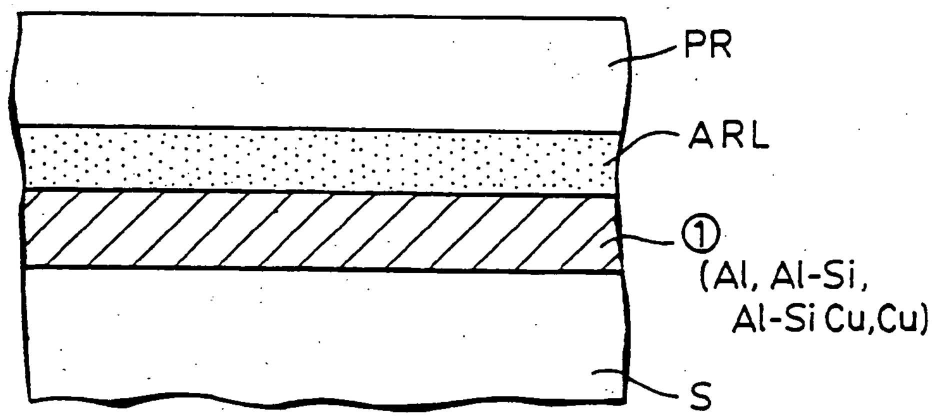
ARL: anti-reflective layer (SiC)

G : High melting metal silicide (WSi gate)

S: Substrate

Fig.28

Structure of example



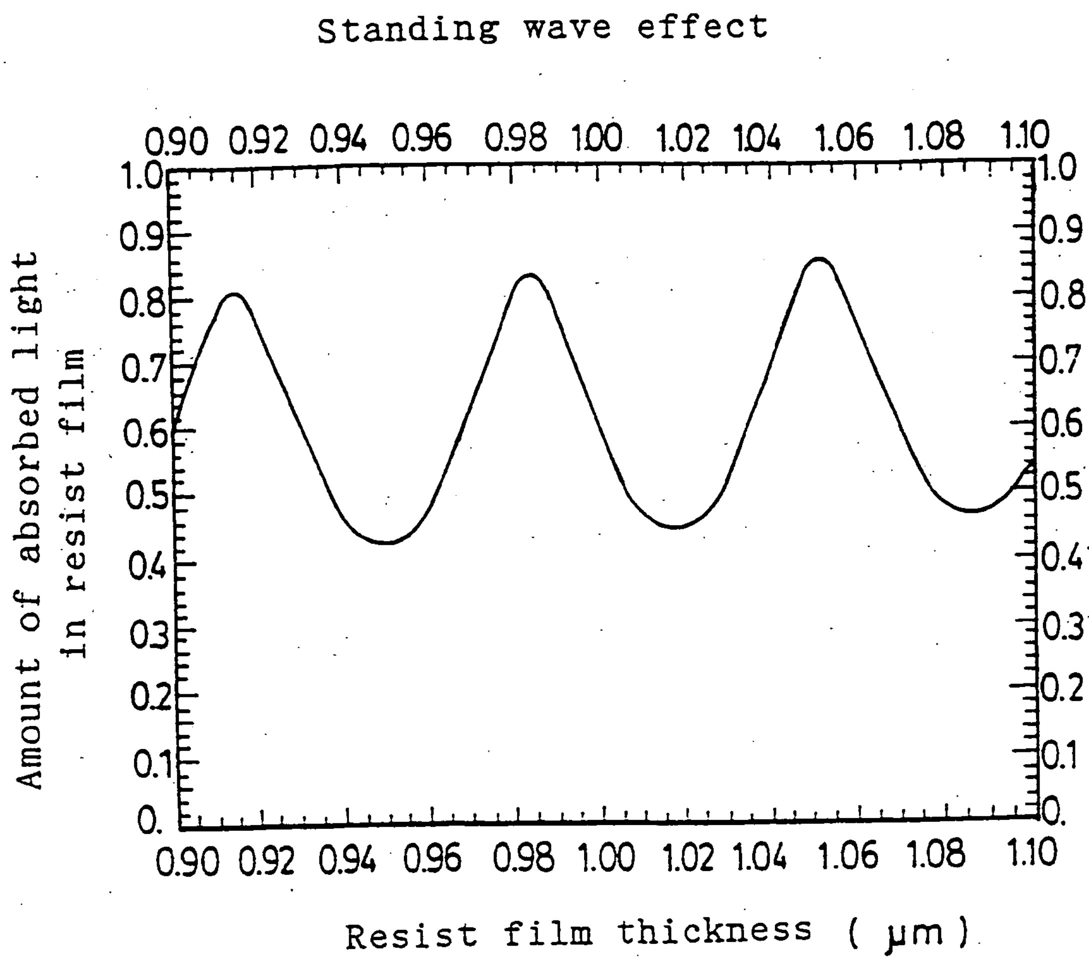
PR: photoresist

ARL: anti-reflective layer (SiC or SiO)

1 : Al series metal wiring material

S: Substrate

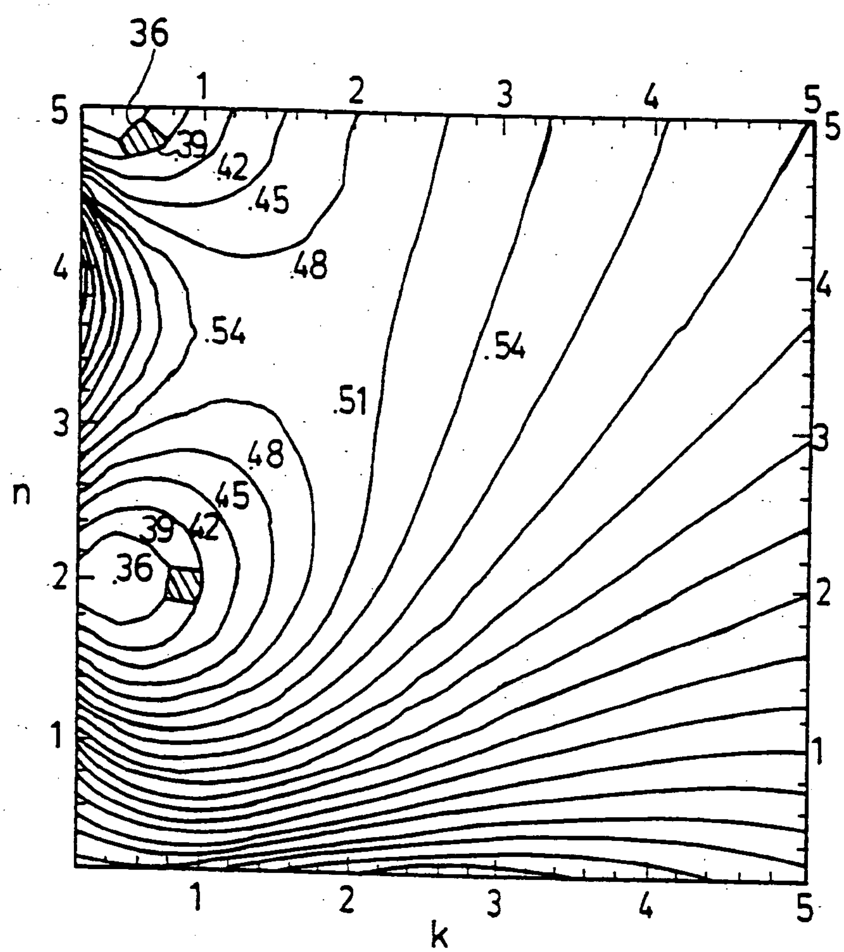
Fig.29



λ = 248 nm
XP8843 on Al-Si ,
n_{PR} = 1.802 , k_{PR} = 0.0107
n_{sub} = 0.089 , k_{sub} = 2.354

Fig.30

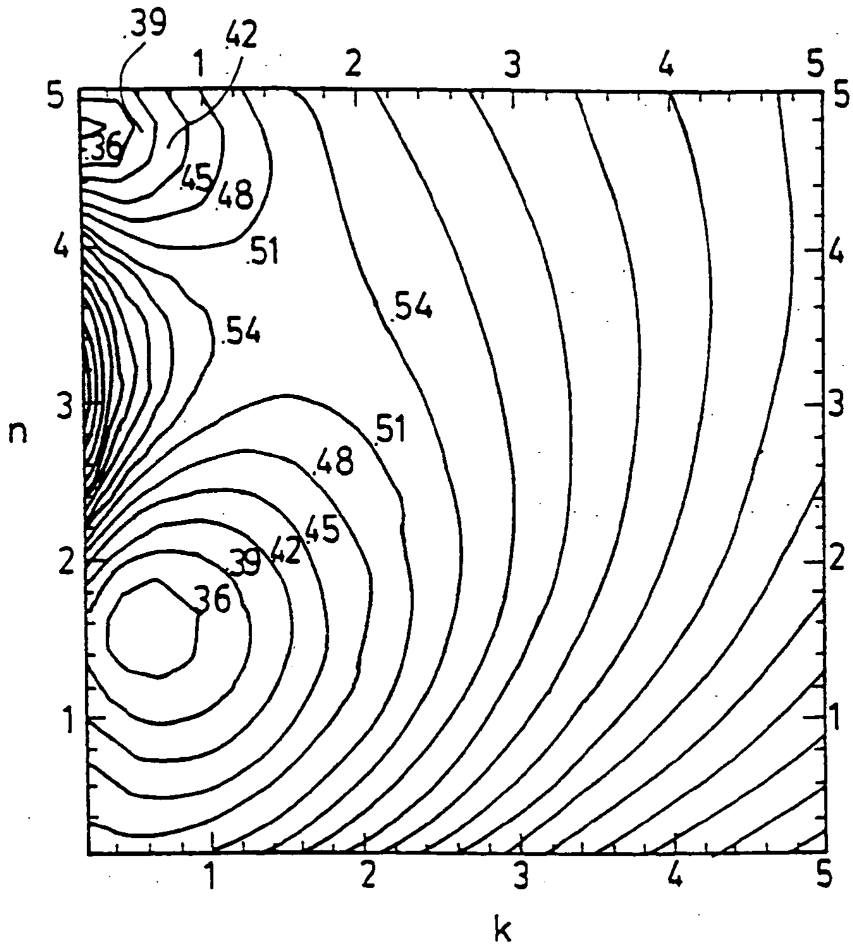
Trace of fluctuation at resist film thickness of 982 nm



λ = 248 nm,
XP8843 / ARL / Al, Al-Si, Al-Si-Cu,
n_{PR} = 1.802, k_{PR} = 0.0107, d_{PR} = 982 nm,
n_{arl}, k_{arl} : parameter, d_{arl} = 30 nm,
n_{sub} = 0.089, k_{sub} = 2.354

Fig.31

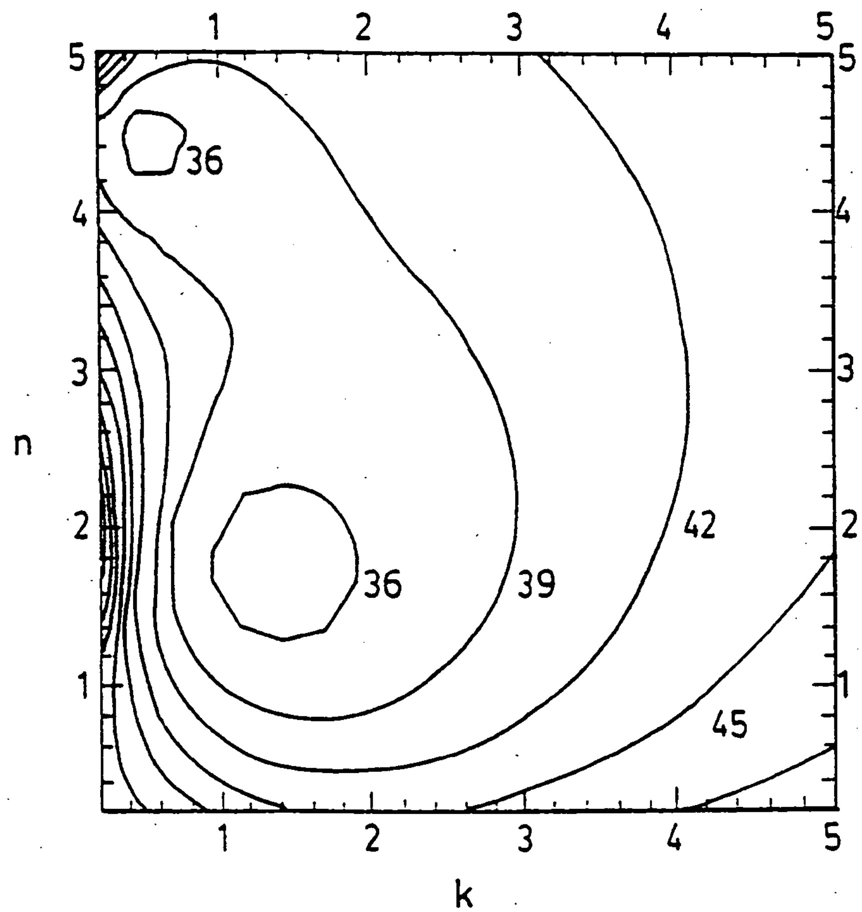
Trace of fluctuation at resist film thickness of 1000 nm



λ = 248 nm
XP8843 / ARL / Al, Al-Si, Al-Si-Cu,
n_{PR} = 1.802 , k_{PR} = 0.0107 , d_{PR} = 1000nm,
n_{arl} , k_{arl} : parameter , d_{arl} = 30nm,
n_{sub} = 0.089 , k_{sub} = 2.354

Fig.32

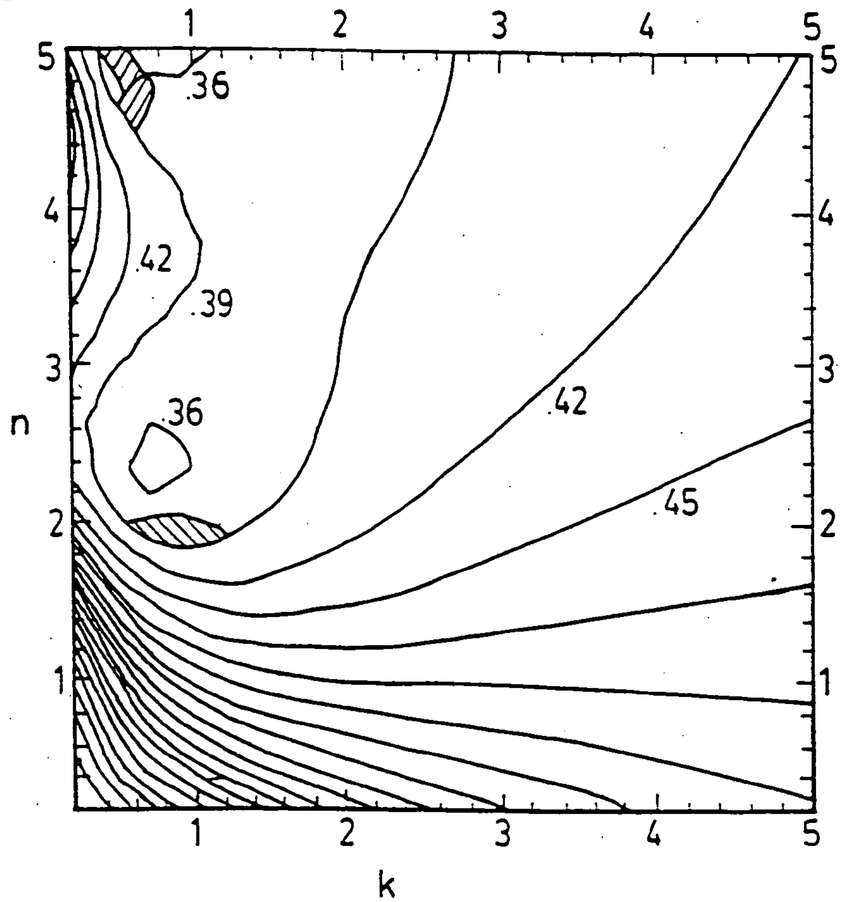
Trace of fluctuation at resist film thickness of 1018 nm



$\lambda = 248\,nm$,
XP8843 / ARL / Al, Al-Si, Al-Si-Cu,
$n_{PR} = 1.802$, $k_{PR} = 0.0107$, $d_{PR} = 1018\,nm$,
n_{arl}, k_{arl} : parameter, $d_{arl} = 30\,nm$,
$n_{sub} = 0.089$, $k_{sub} = 2.354$

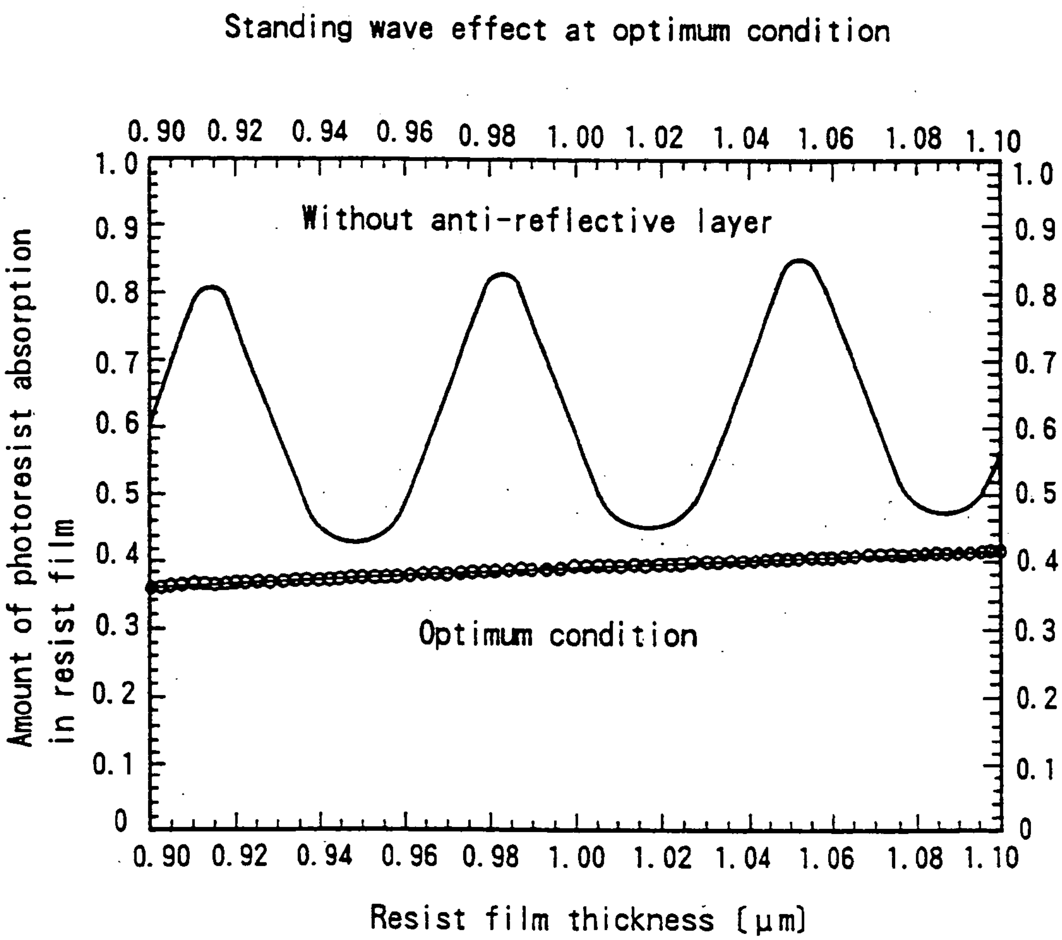
Fig.33

Trace of fluctuation at resist film thickness of 1035 nm



$\lambda = 248\,nm$,
XP8843 / ARL / Al, Al-Si, Al-Si-Cu,
$n_{PR} = 1.802$, $k_{PR} = 0.0107$, $d_{PR} = 1035\,nm$,
n_{arl}, k_{arl} : parameter, $d_{arl} = 30\,nm$,
$n_{sub} = 0.089$, $k_{sub} = 2.354$

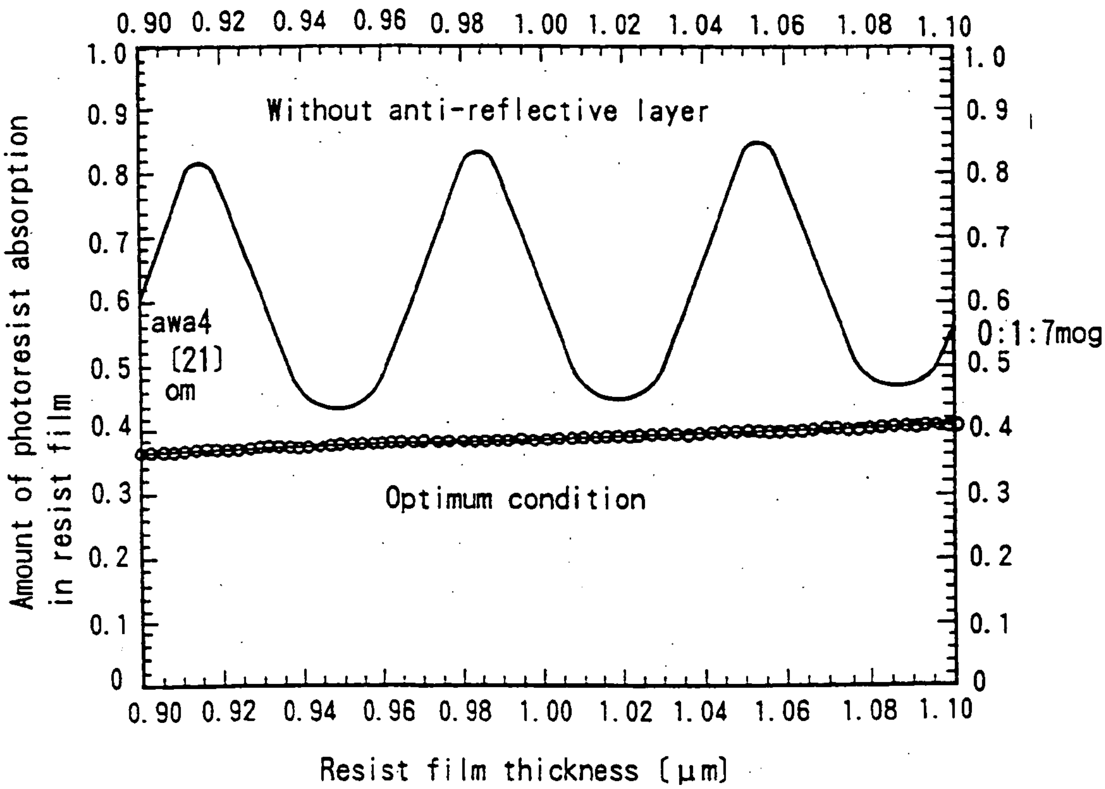
FIG.34



λ=248nm
XP8843/ARL/W-Si,
n_{PR}=1.802, k_{PR}=0.0107,
n_{arl}=4.8, k_{arl}=0.45, d_{arl}=30nm,
n_{sub}=0.089, k_{sub}=2.354

FIG.35

Standing wave effect at optimum condition



λ =248nm,
XP8843/ARL/Al-Si,
n_{PR}=1.802, k_{PR}=0.0107,
n_{arl}=2.0, k_{arl}=0.8, d_{arl}=30nm,
n_{sub}=0.089, k_{sub}=2.354

Fig.36

Relation between anti-reflective layer thickness and R

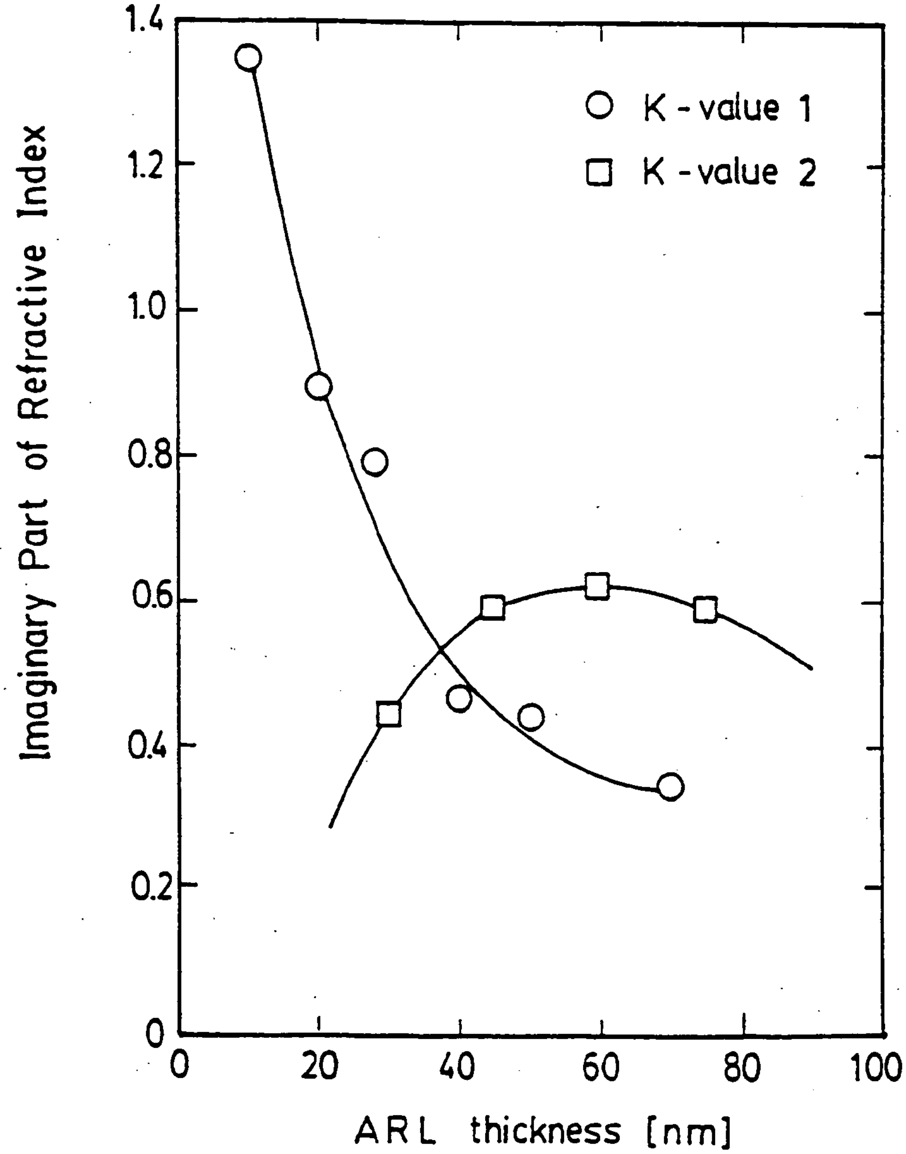
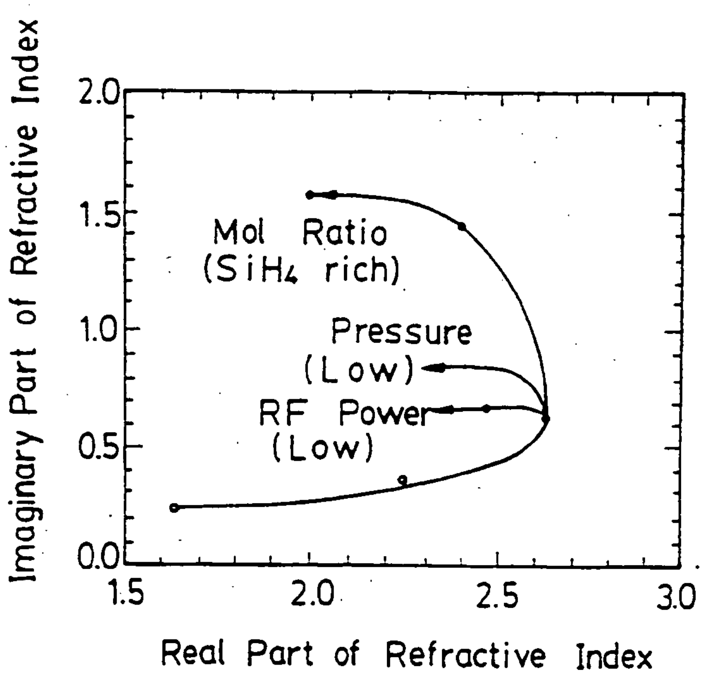


Fig.37

Figure showing dependence of n, k value of SiC film on film forming condition

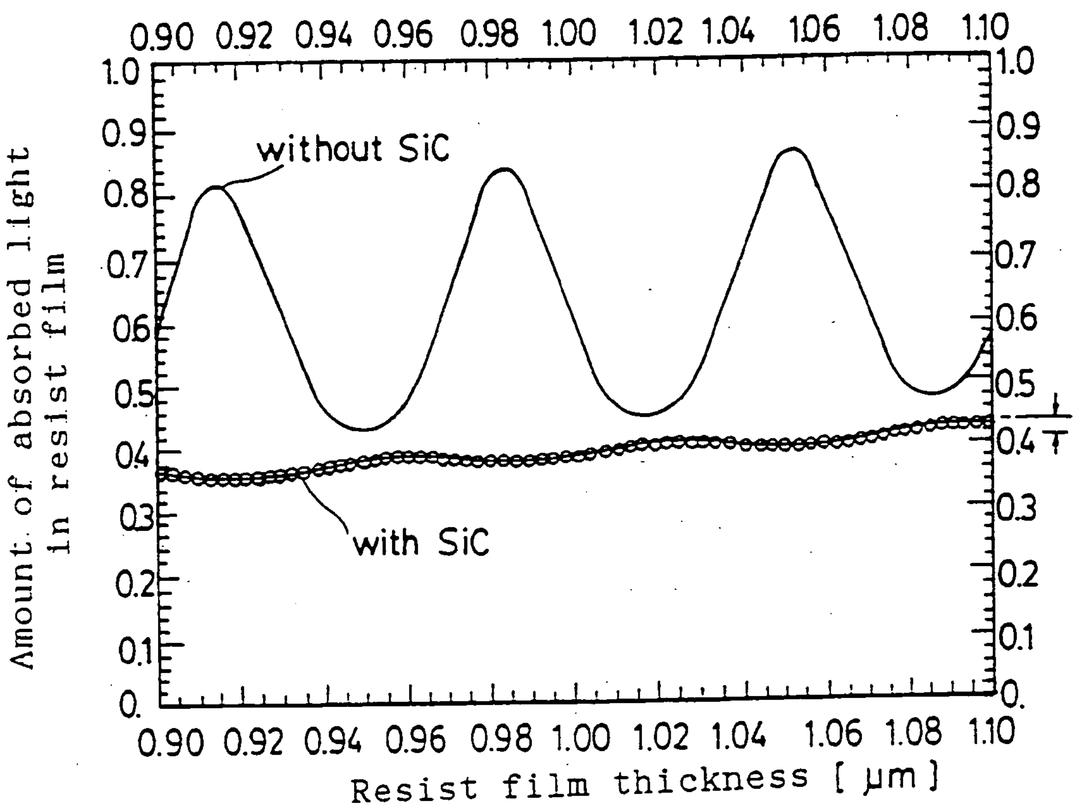
Dependence of optical property (n value, k value) of SiC film on deposition condition



System Bias-ECR Plasma CVD
Gas SiH_4, C_2H_4
Flow Rata (sccm) SiH_4 : 5 - 10
C_2H_4 :2.5-10
Pressure (Pa) 0.04 - 0.533
RF Power (W) 300 - 900

Fig.38

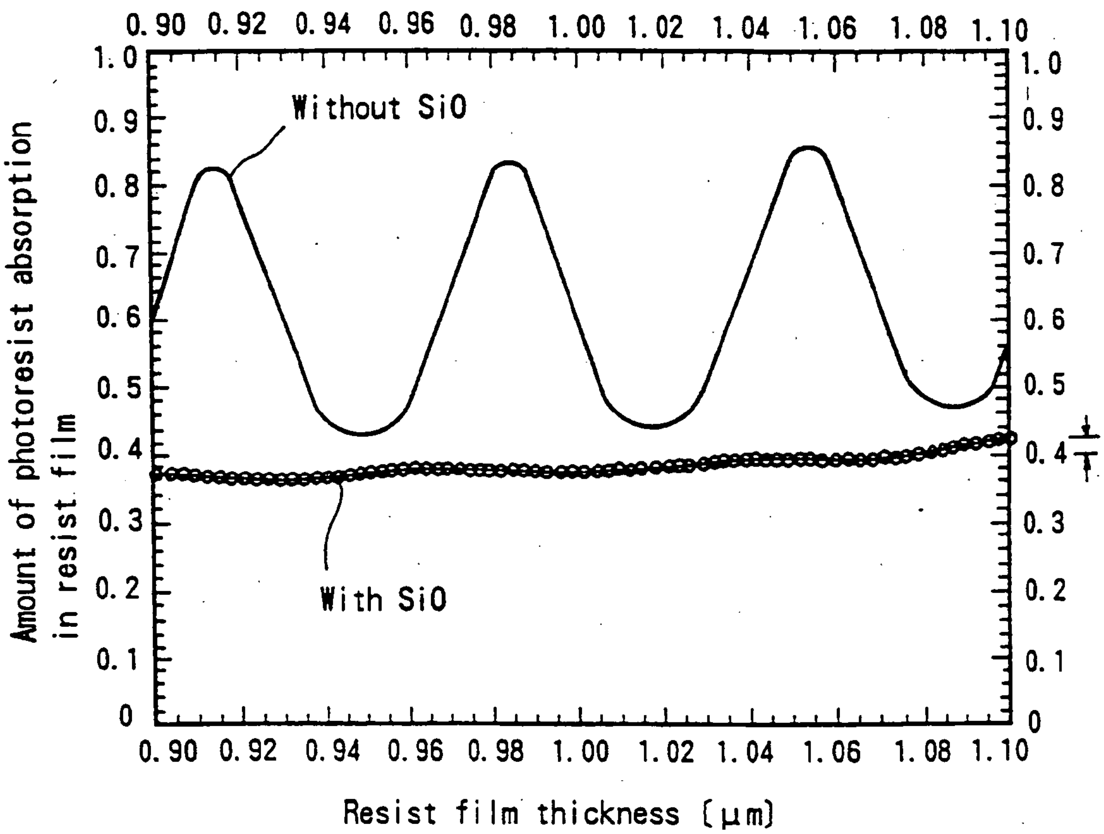
Anti-reflective effect of SiC film (20 nm) on Al, Al-Si, Al-Si-Cu (Example 1)



XP8843 / SiC(20nm) / Al-Si, Al-Si-Cu, Al,
$n_{sic} = 2.3$, $k_{sic} = 0.81$

FIG.39

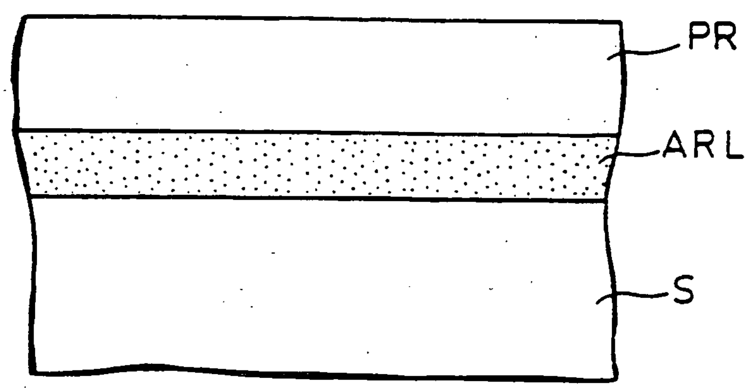
Anti-reflective effect of SiO film (30nm) on Al, Al-Si, Al-Si-Cu (Example 7)



XP8843/SiO(30nm)/Ai, Al-Si, Al-Si-Cu,
n_{SiO}=1.83 k_{SiO}=0.75

Fig.40

Structure of example

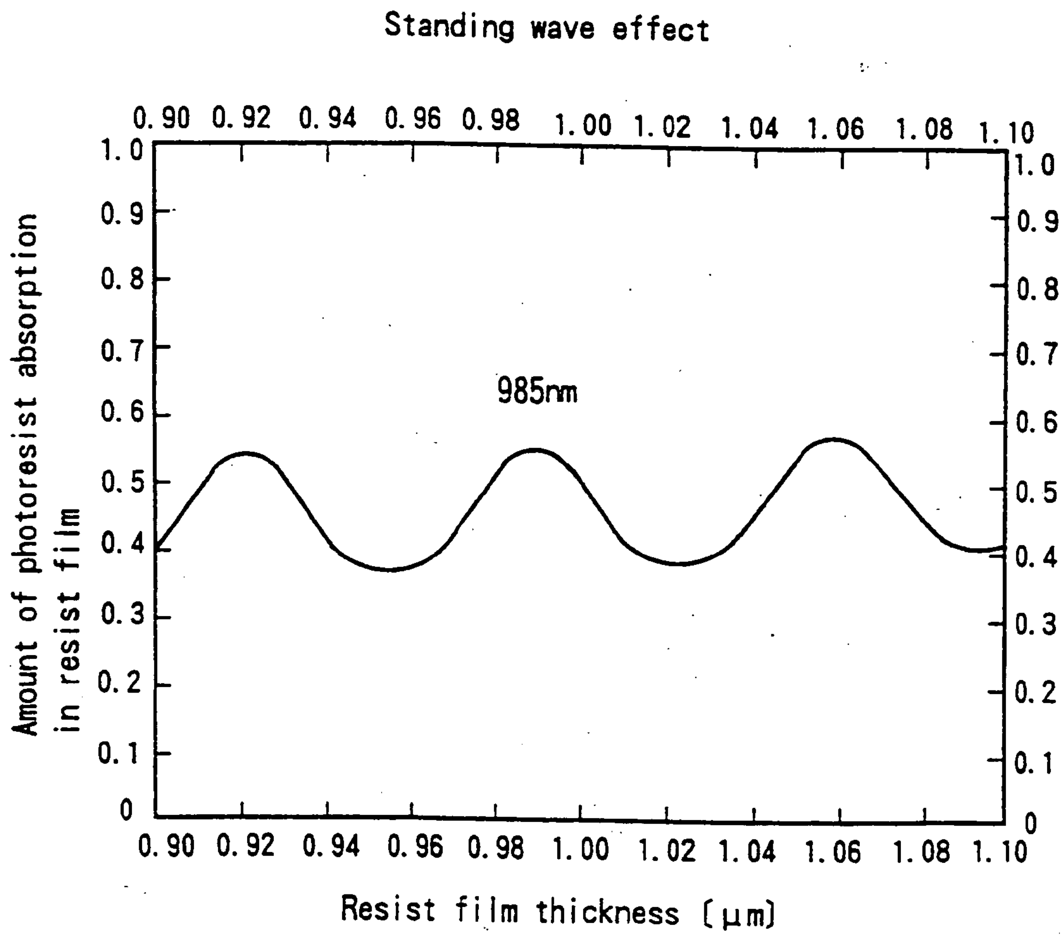


PR: photoresist

ARL: anti-reflective layer (SiC or SiO)

S: Si substrate

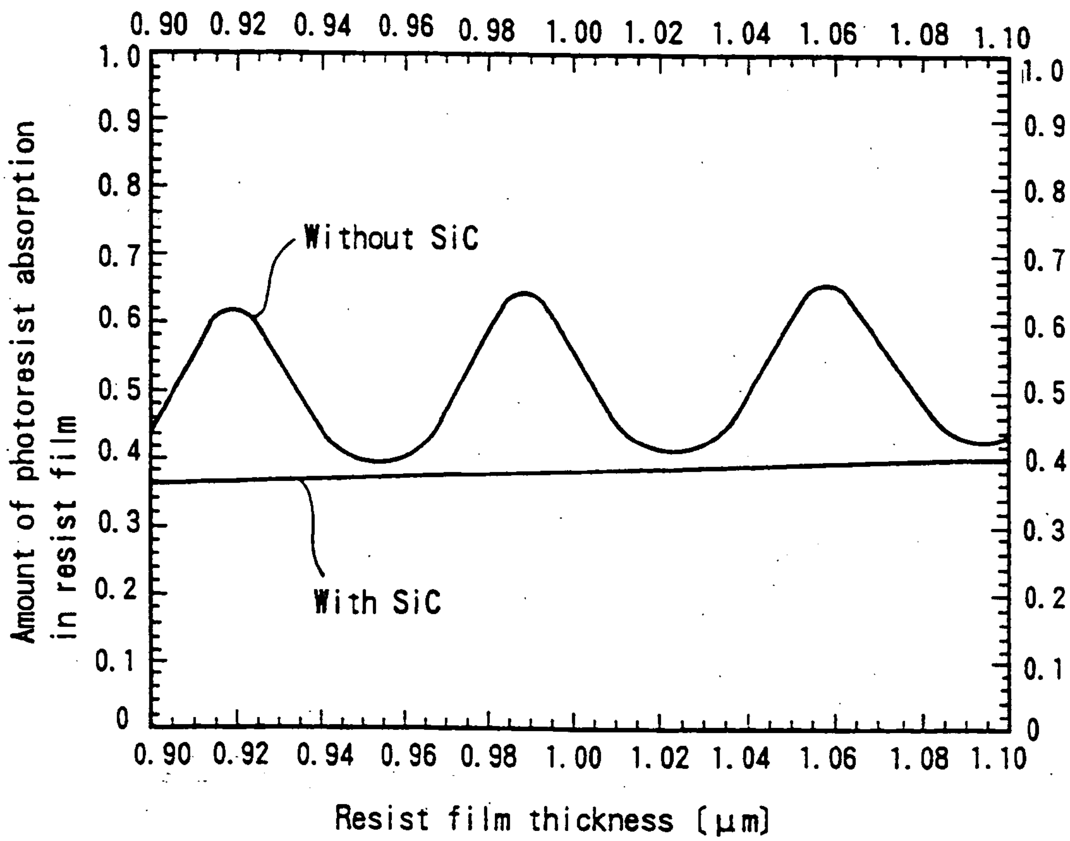
FIG.41



λ=248nm, n_{PR}=1.802, k_{PR}=0.0107,
XP8843onSi, n_{sub}=1.96, k_{sub}=2.69

FIG.42

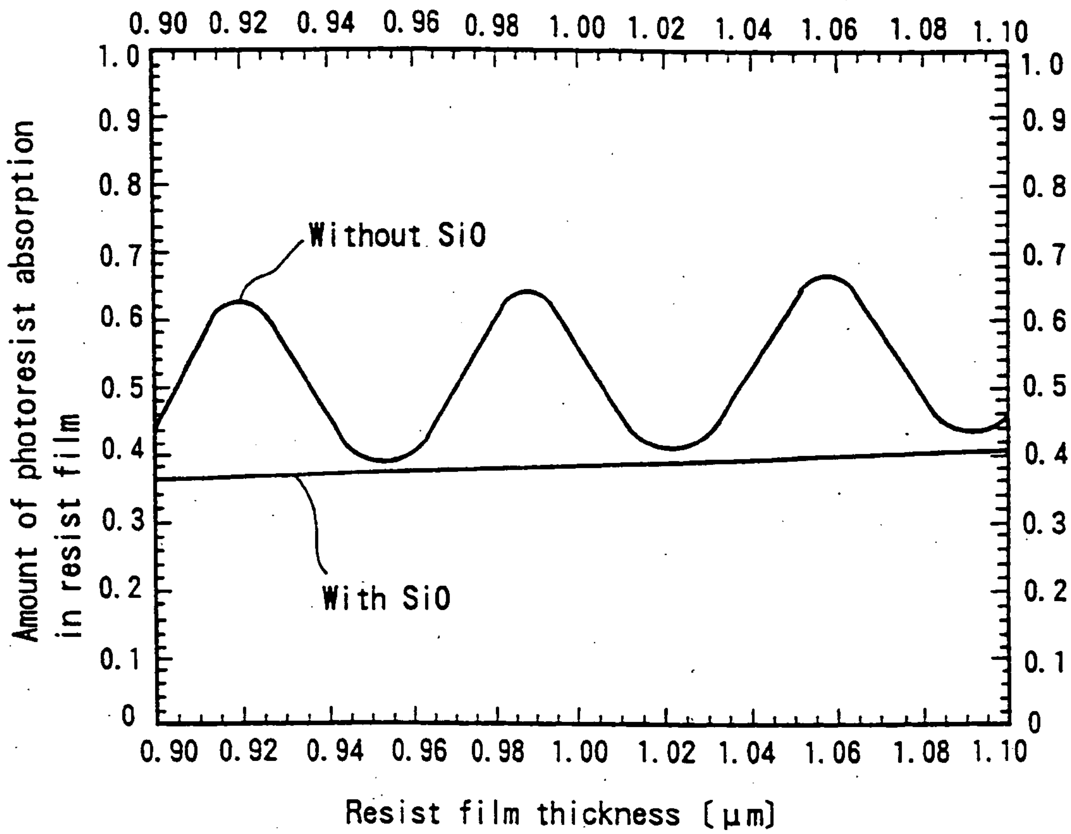
Anti-reflective effect of SiC film (25nm) on Si substrate (Example 1)



XP8843/SiC(25nm)/Si,
n_{SiC}=2.3, k_{SiC}=0.65

FIG.43

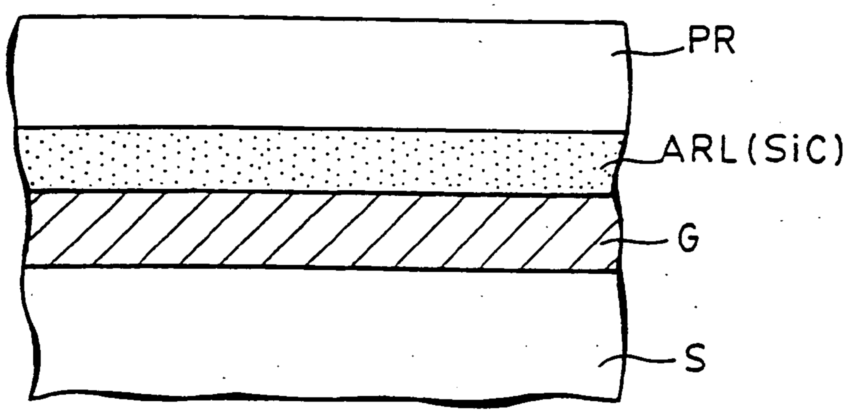
Anti-reflective effect of SiO film (30nm) on Si substrate (Example 2)



XP8843/SiO(30nm)/Si,
n_{SiO}=2.1, k_{SiO}=0.7

Fig.44

Structure of example



PR: photoresist

ARL: anti-reflective layer (SiC)

G: high melting metal silicide (WSi gate)

S: substrate

Fig.45

SiO film forming behavior by ECR-CVD

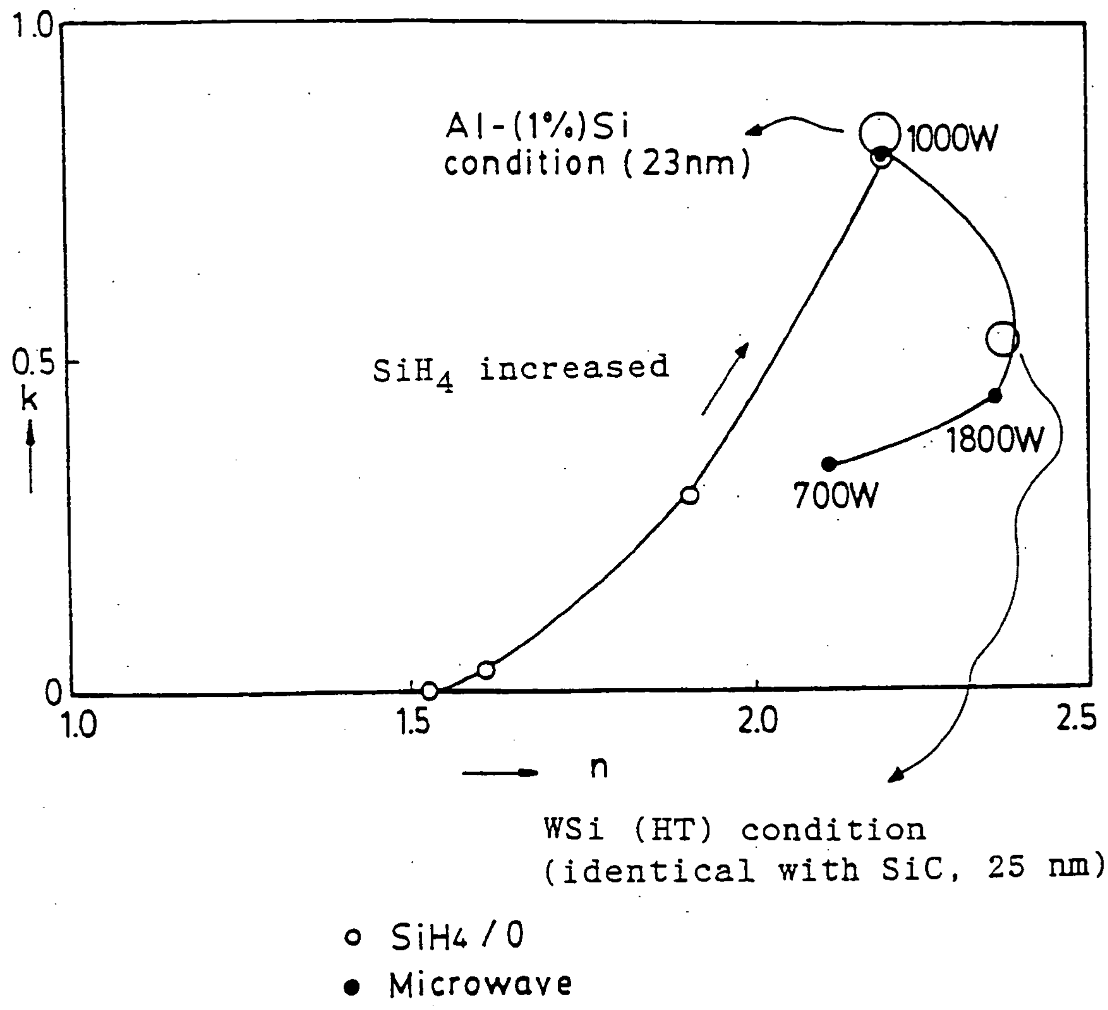
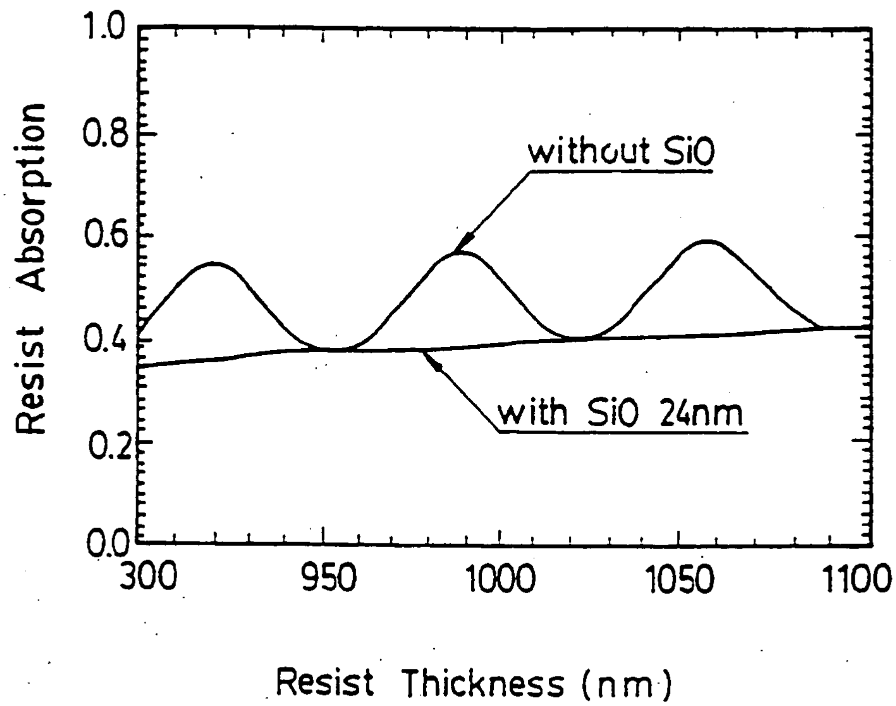


Fig.46

Anti-reflective effect of SiO (24 nm) on W-Si



Condition

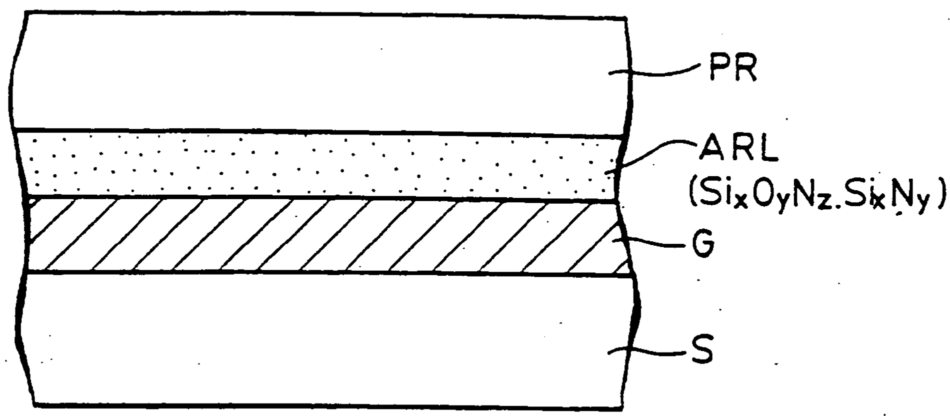
substate : W-Si
(n = 1.93, k = 2.73)
ARL : optimized SiOx
(n : 2.36, k = 0.53, d = 23.8nm)
photoresist : XP8843
(n = 1.80, k = 0.011)

ARL effect

	without SiOx	with SiOx
Max	0.60	0.425
Min	0.40	0.410
Swing ratio	±21%	±1.8 %

Fig.47

Structure of Example 53



PR: photoresist

ARL: anti-reflective film

G: high melting metal silicide (WSi gate)

S: substrate

Fig.48

$Si_xO_yN_z$ film forming behavior by ECR-CVD

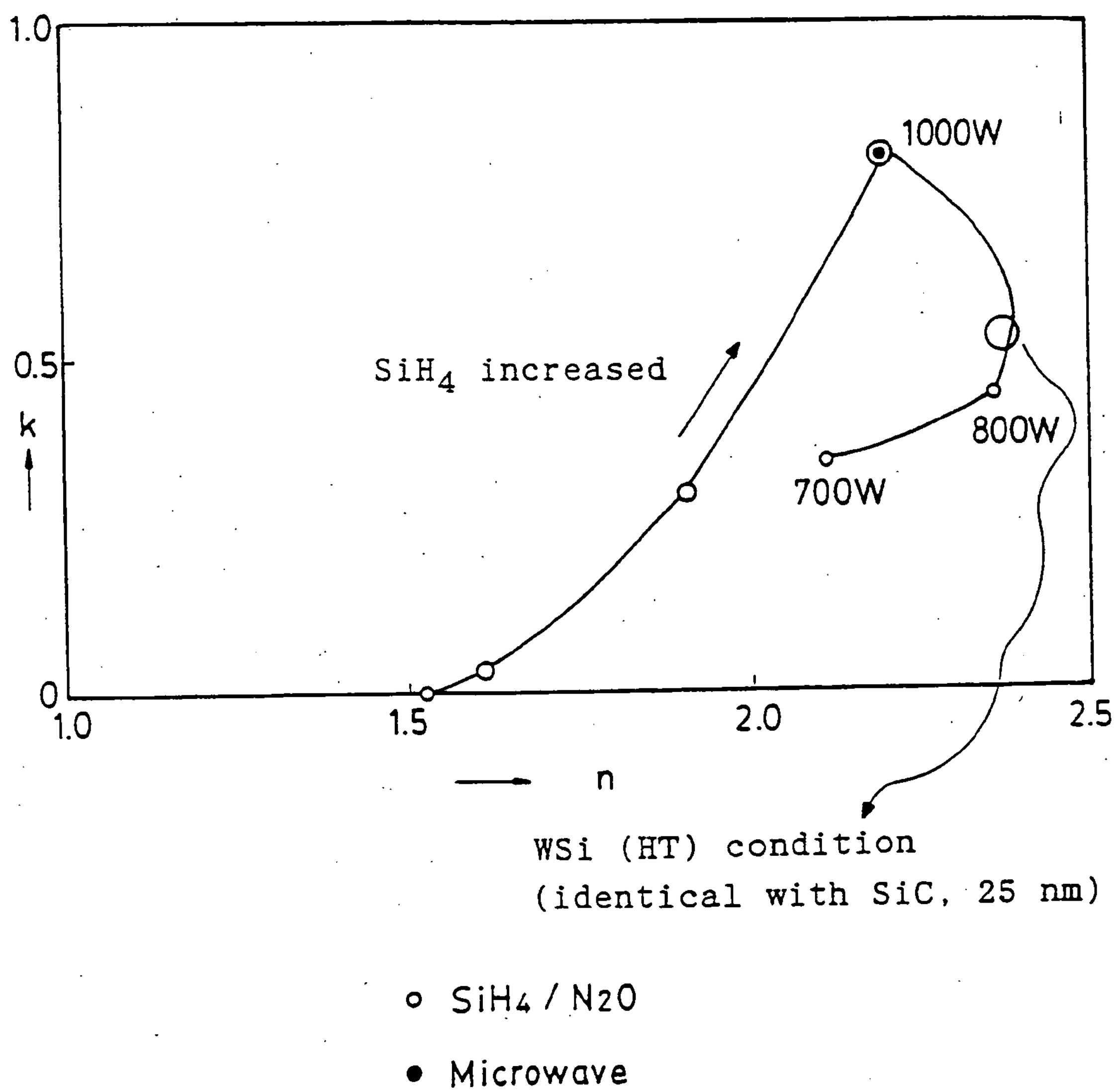
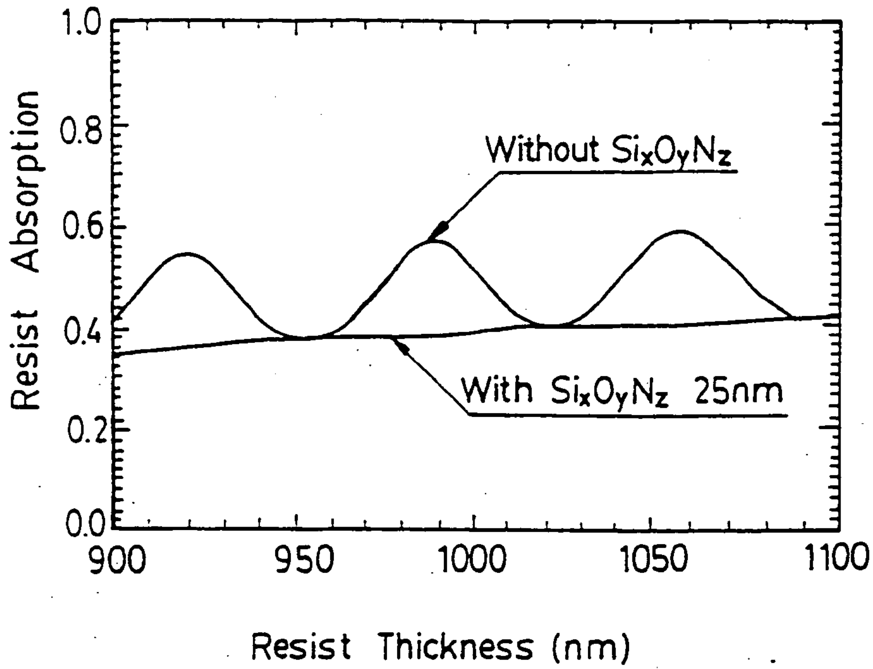


Fig.49

Anti-reflective effect of $Si_xO_yN_z$ (25 nm) on W-Si



Condition

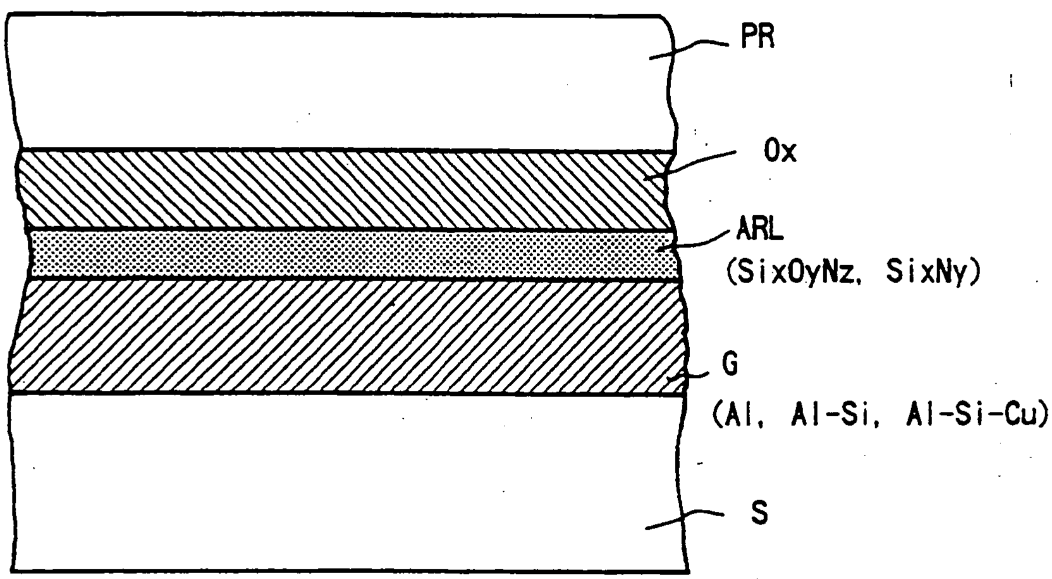
substrate : W - Si
($n = 1.93$, $k = 2.73$)
ARL : optimized $Si_x O_y N_z$
(n : 2.36, $k = 0.53$, $d = 23.8$ nm)
photoresist : X P8843
($n = 1.80$, $k = 0.011$)

ARL effect

	Without $Si_xO_yN_z$	With $Si_xO_yN_z$
Max	0. 60	0. 425
Min	0. 40	0. 410
Swing ratio	±21%	±1. 8%

FIG.50

Structure of Example 65



PR: Photoresist

OX: Oxide film(SiO_2, etc., may be saved)

ARL: Anti-reflective layer

G: Metal wiring meterial

S: Substrate

Fig.51

Optical constant property of $Si_xO_yN_z$, Si_xN_y

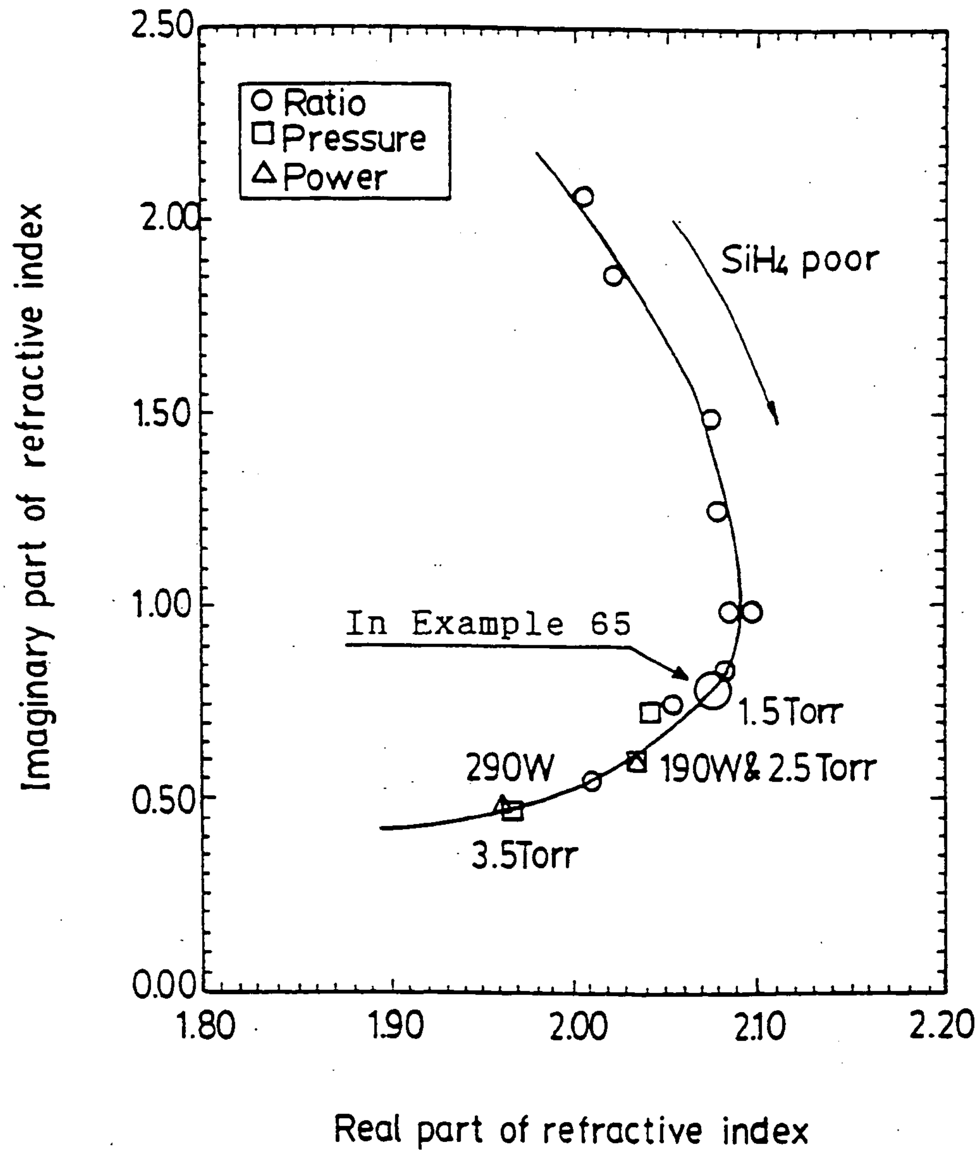
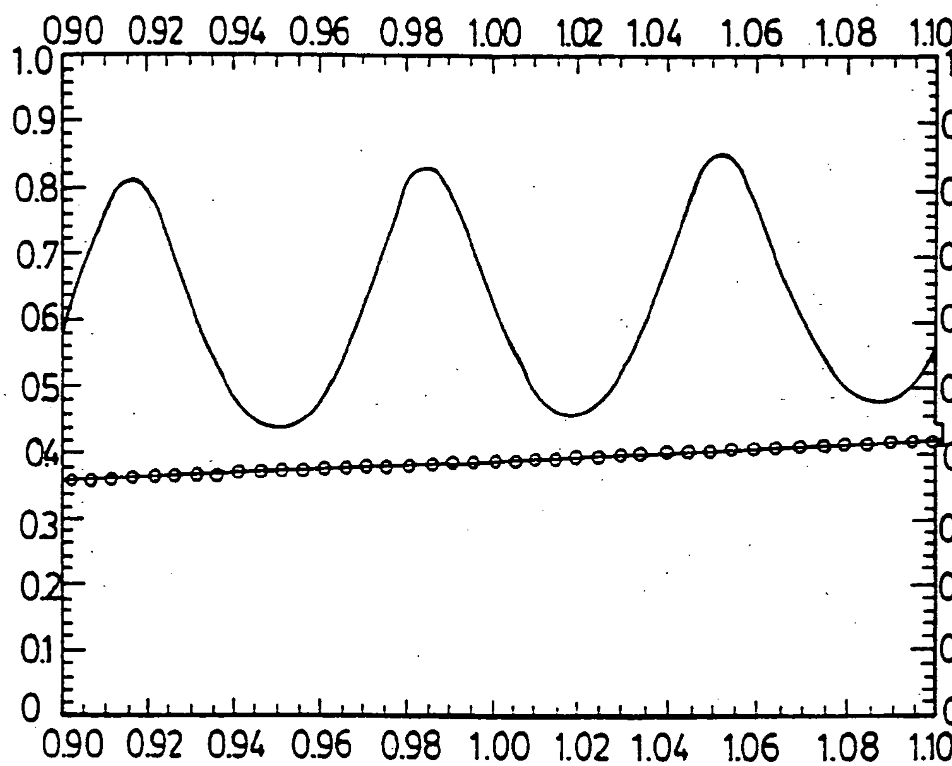


Fig.52

Standing wave effect at optimum condition



SiON for AlSi (KrF)

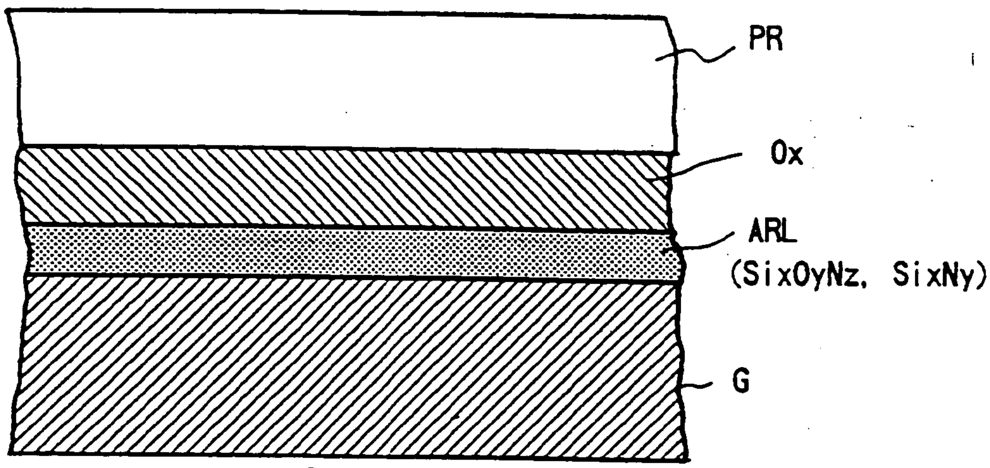
n = 2.08
k = 0.85
d = 0.025 μm

⇒ SiH_4 / N_2O = 0.83

ARL effect: ± 0.48 %

FIG.53

Structure of Example 65



PR: Photoresist

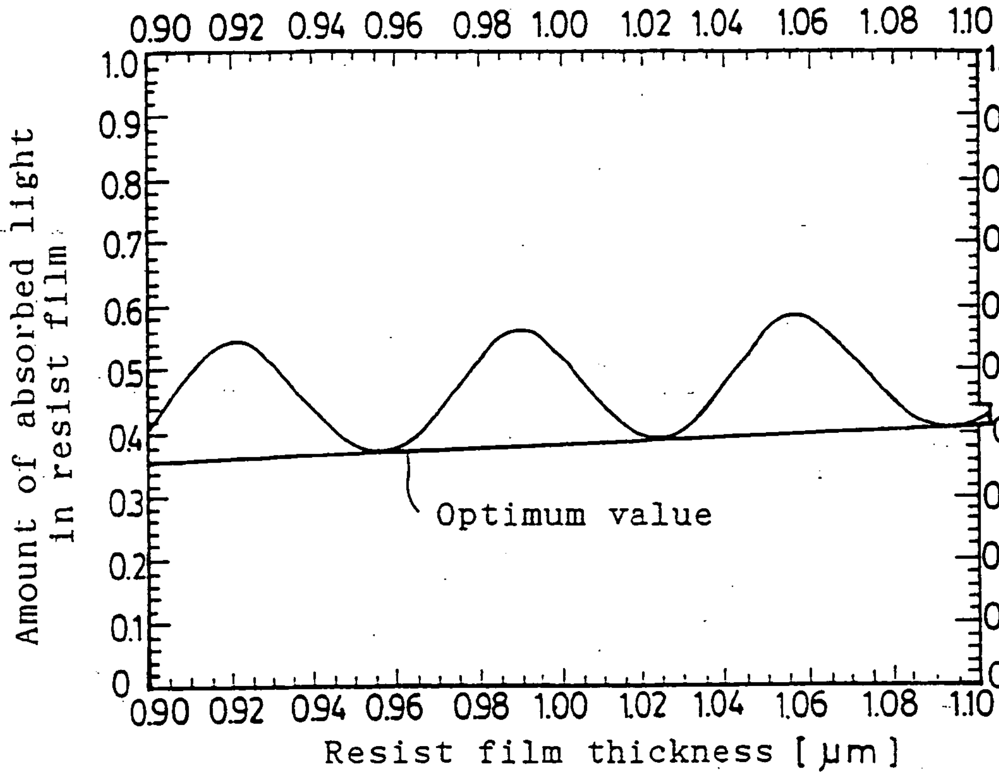
OX: Oxide film(SiO_2, etc., may be saved)

ARL: Anti-reflective layer

G: Silicic material (single crystal silicon, polycrystalline silicon, amorphous silicon, doped polysilicon)

Fig.54

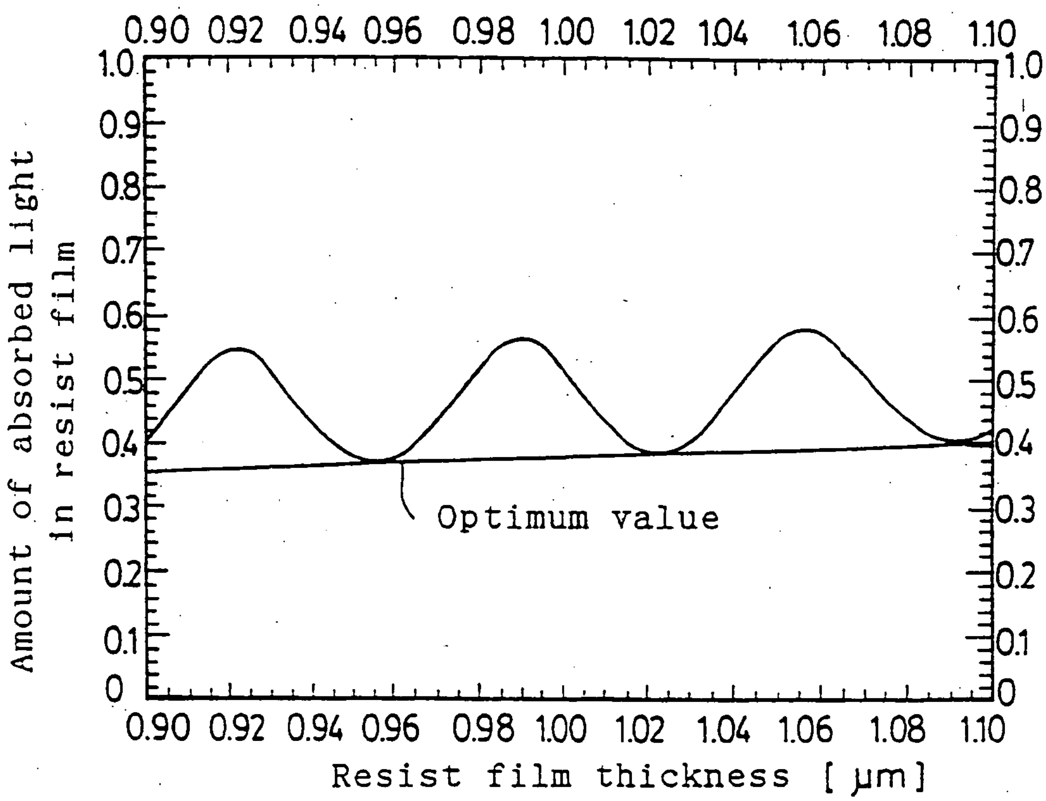
Anti-reflective effect of $Si_xO_yN_y$ film, Si_xN_y film (32 nm) on Si substrate



X P8843/$Si_xO_yN_z$, Si_xN_y (32nm) /Si
$nSi_xO_yN_z = 2.0$
$kSi_xO_yN_z = 0.55$

Fig.55

Anti-reflective effect of $Si_xO_yN_y$ film, Si_xN_y film (100 nm) on Si substrate



XP8843/$Si_xO_yN_z$, Si_xN_y (100nm)/Si

n_{ar1}=1.9

k_{ar1}=0.35

Fig.56

Optical constant property of $Si_xO_yN_z$, Si_xN_y

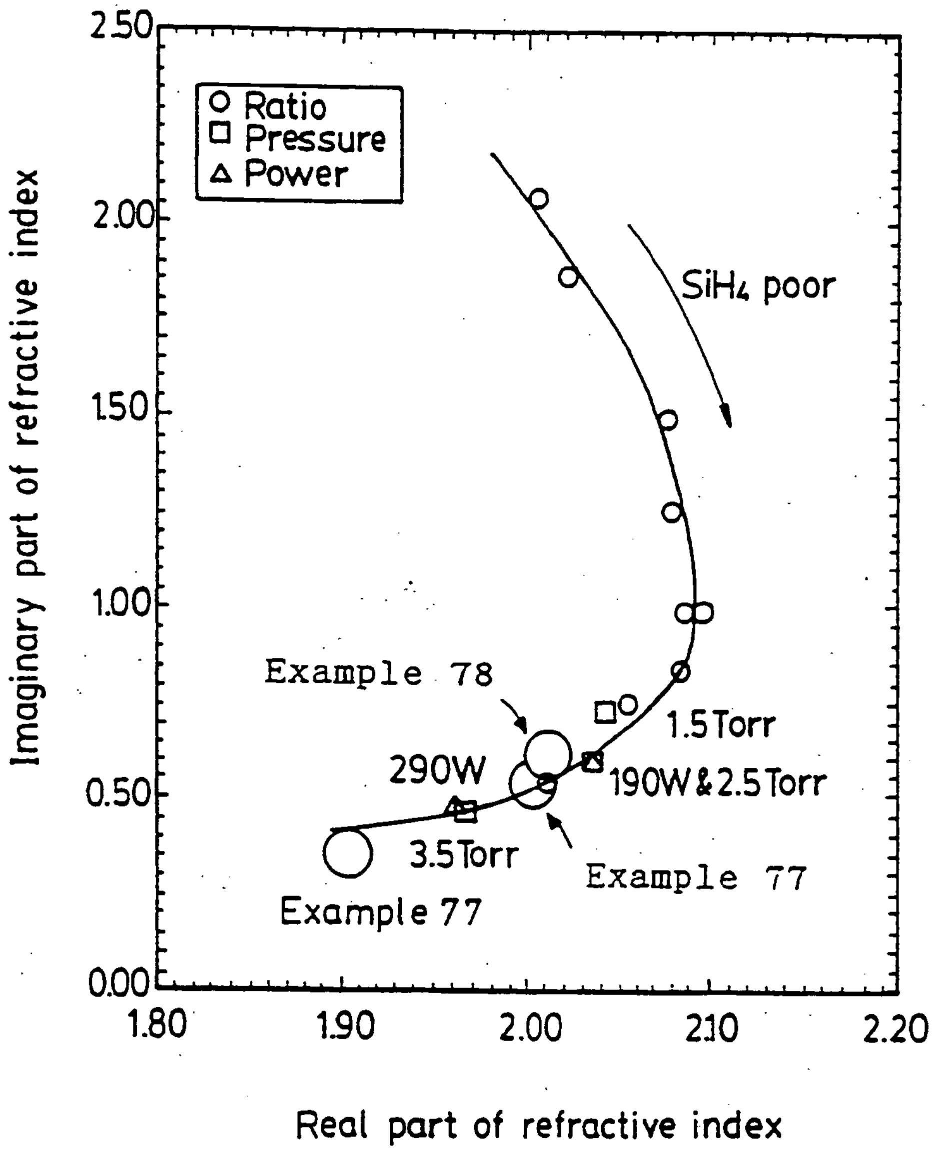
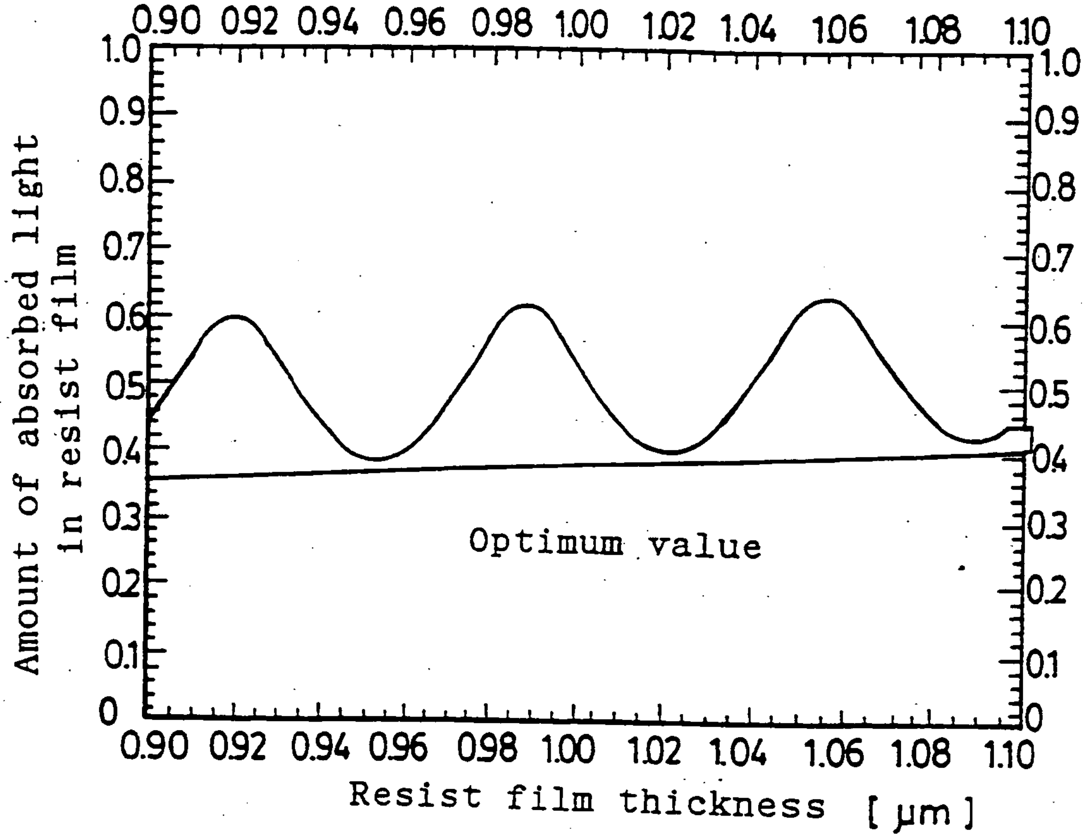


Fig.57

Anti-reflective effect of $Si_xO_yN_z$, Si_xN_y film (33 nm) on Poly-Si, amorphous silicon, doped polysilicon substrate



XP8843/ SixOyNz, SixNy(33nm) / Poly-Si, amorphous-Si, doped polysilicon,

$n_{PR} = 1.801$, $k_{PR} = 0.0107$,

$n_{arl} = 2.01$, $k_{arl} = 0.62$, $d_{arl} = 3.3nm$

$n_{poly} = 1.71$, $k_{poly} = 3.3$

Fig.58

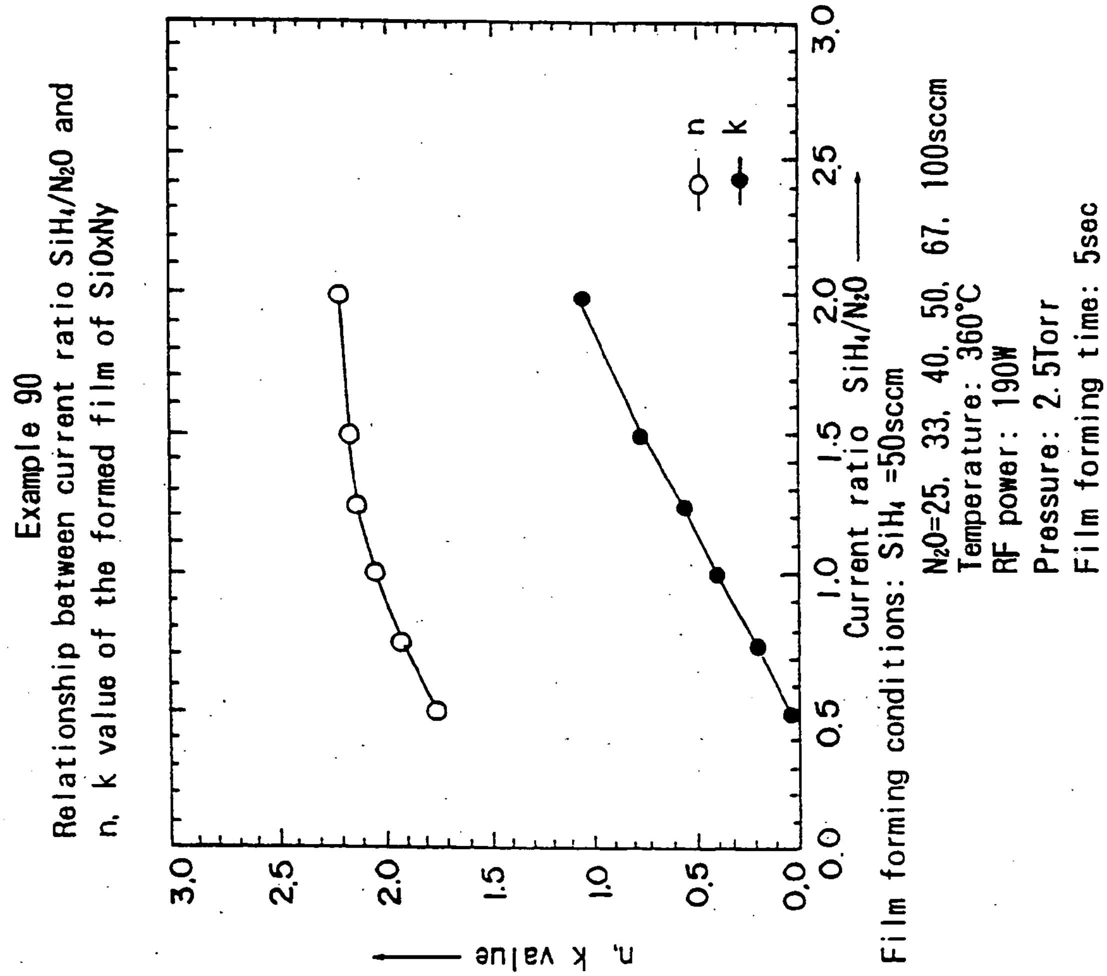
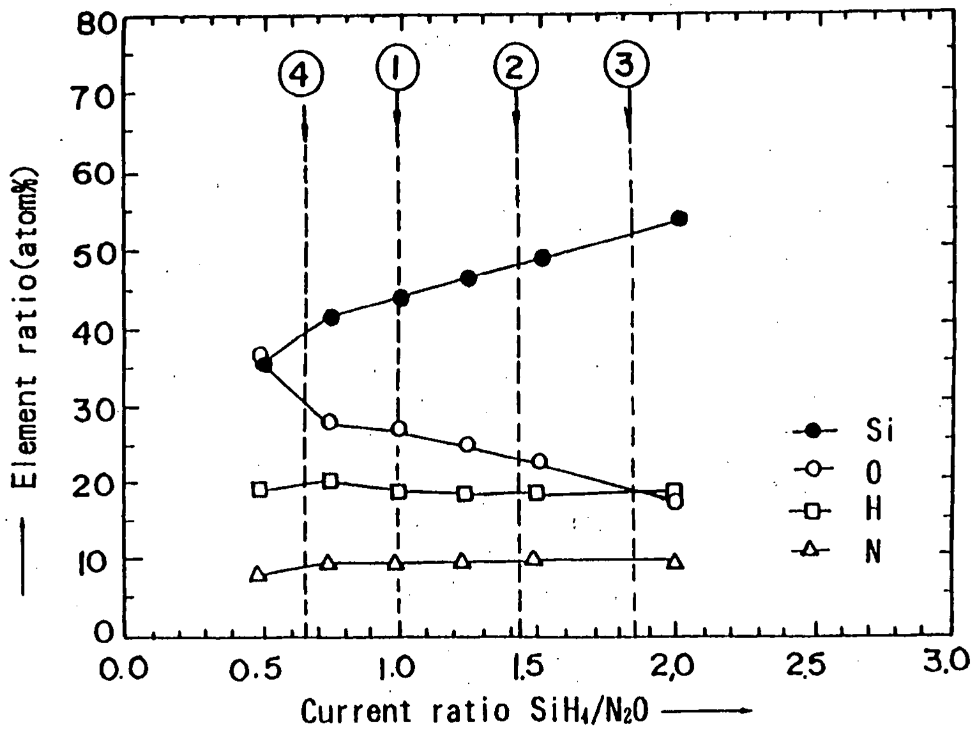

Example 90
Relationship between current ratio SiH₄/N₂O and
n, k value of the formed film of SiOxNy
n, k value
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
n
k
Current ratio SiH₄/N₂O
Film forming conditions: SiH₄ =50sccm
N₂O=25, 33, 40, 50, 67, 100sccm
Temperature: 360°C
RF power: 190W
Pressure: 2.5Torr
Film forming time: 5sec

Fig.59

Example 90

Relationship between current ratio SiH_4/N_2O and element raitio of Si, O, N, H, (RBS value) of the formed film of SiOxNy



Film forming conditions: As same in Fig. 58 other than the film forming time is 40 sec

Fig.60

IR spectrum of film formed in Example 90

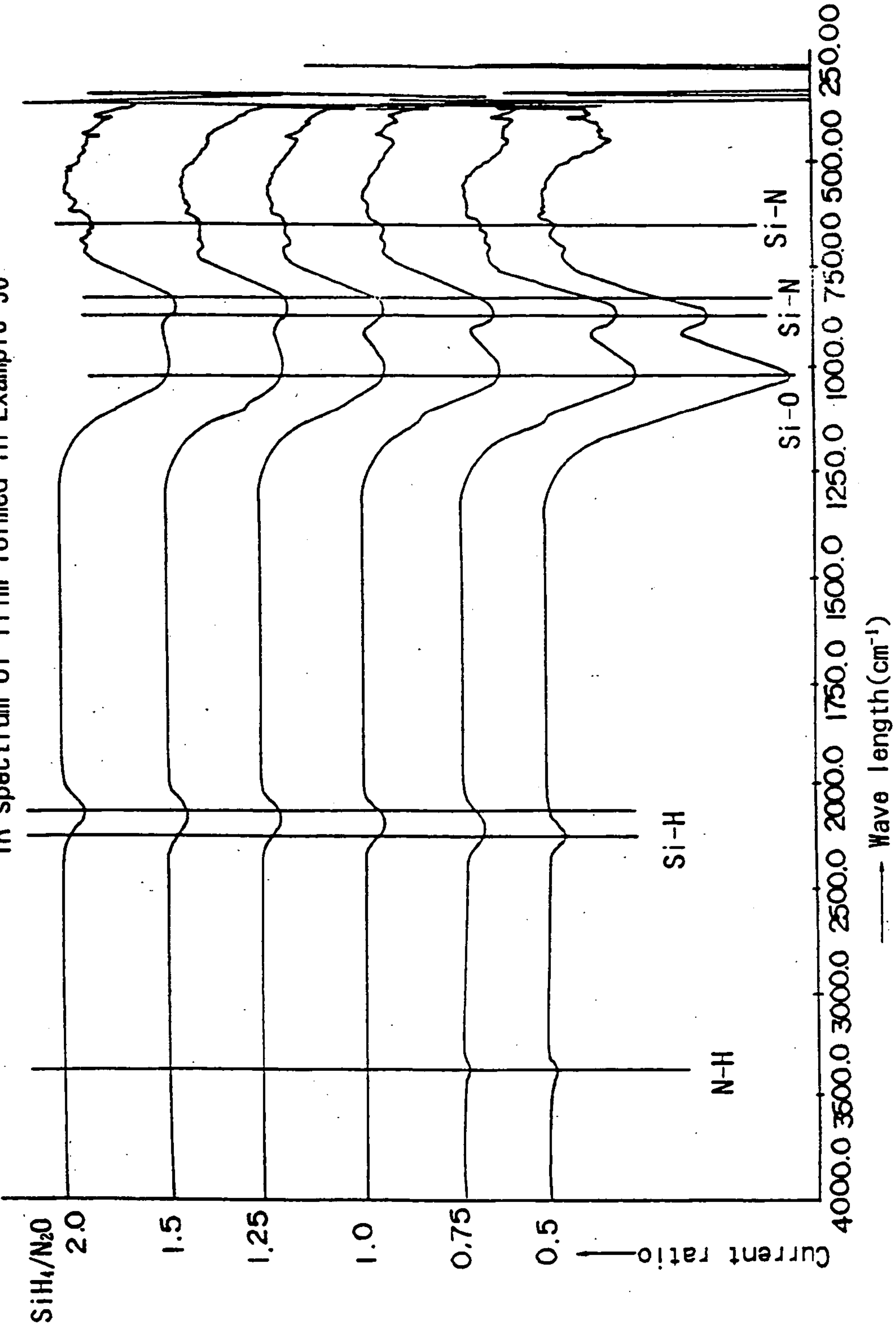
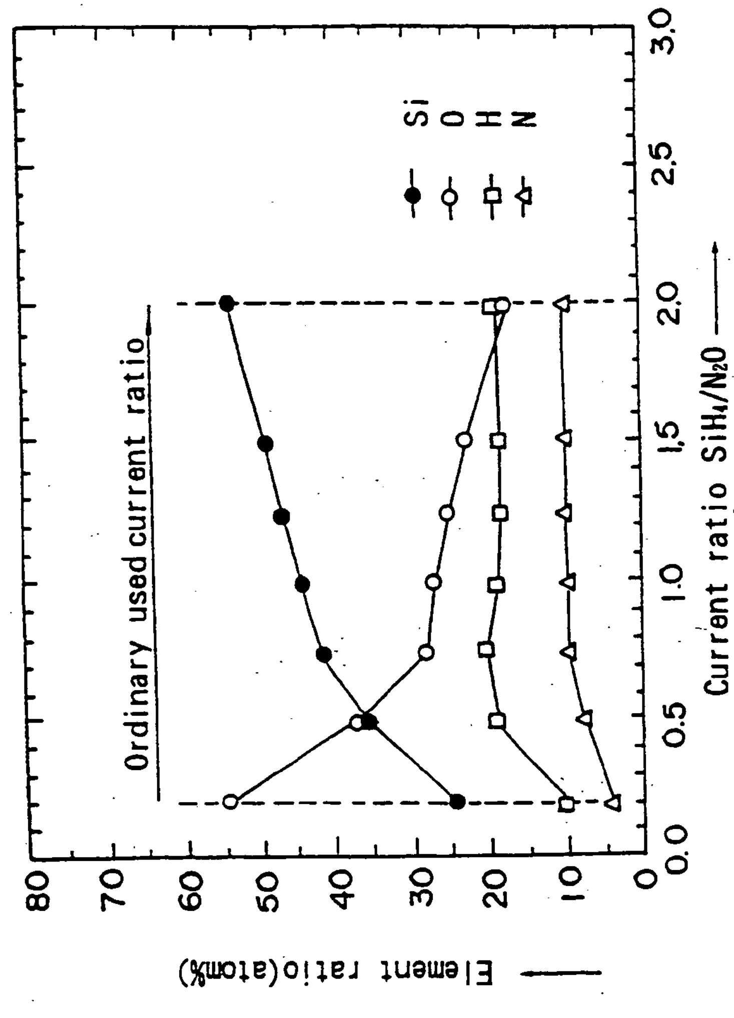


Fig.61

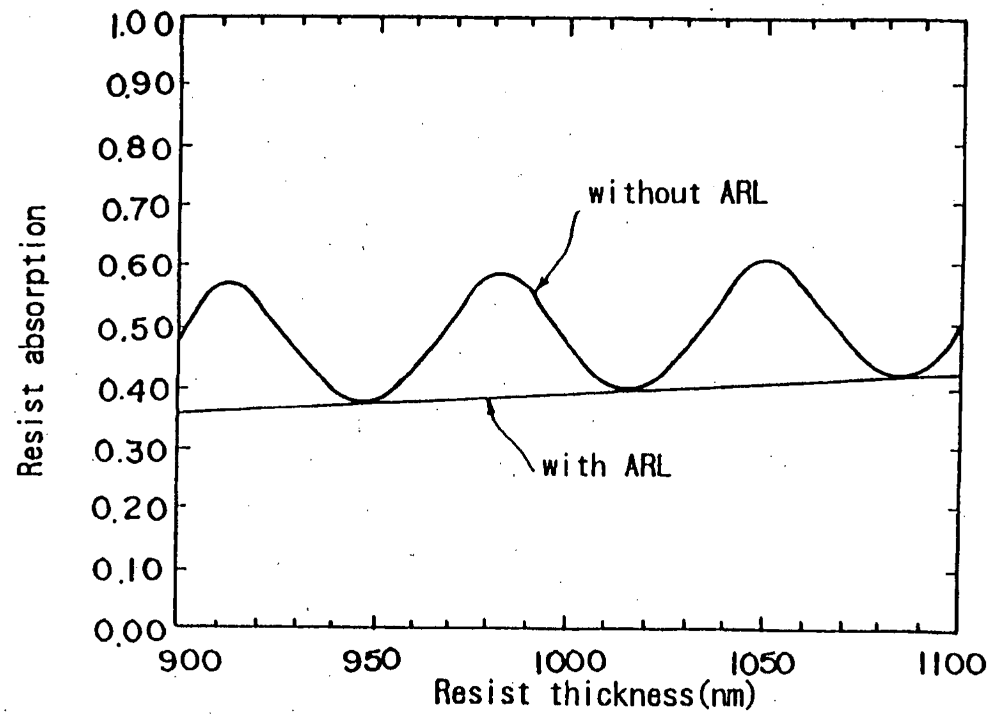
Ordinary used current ratio of SiH_4/N_2O for forming SiOxNy film



Film forming conditions: As same in Fig. 59

Fig.62

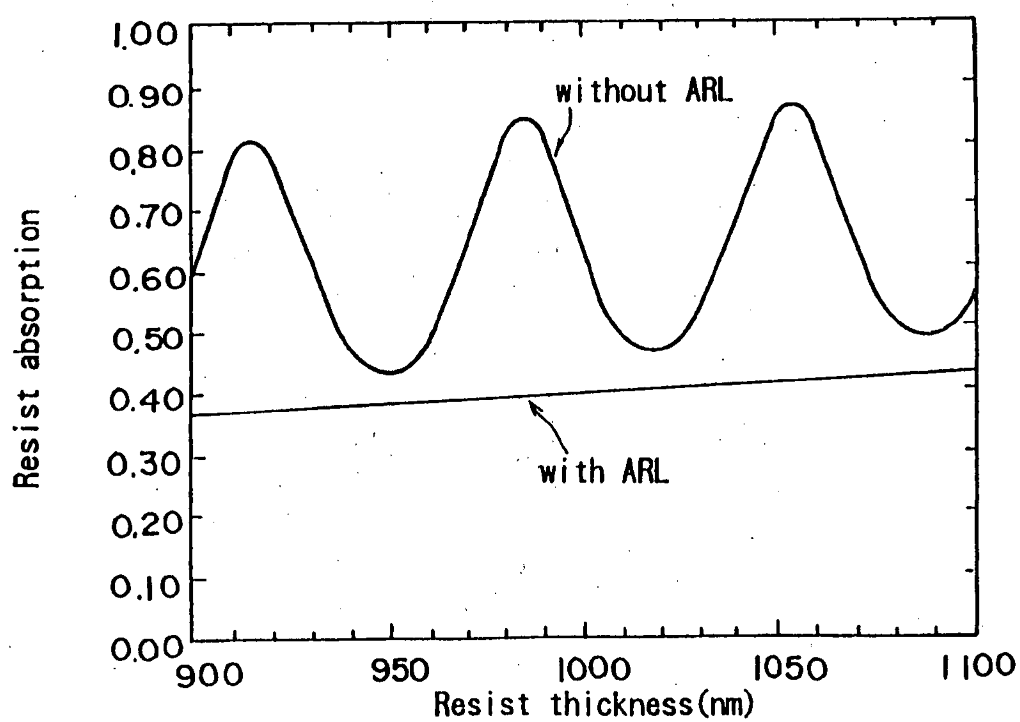
Anti-reflective effect of the film formed in Example 90 (simulation) on W-Si with SiO_2



Conditions for simulation: Photoresist: n=1.80, k=0.011
SiO_2: n=1.52, k=0, d=170nm
SiOxNy(Hz): n=2.12, k=0.52, d=29nm
W-Si: n=1.93, k=2.73

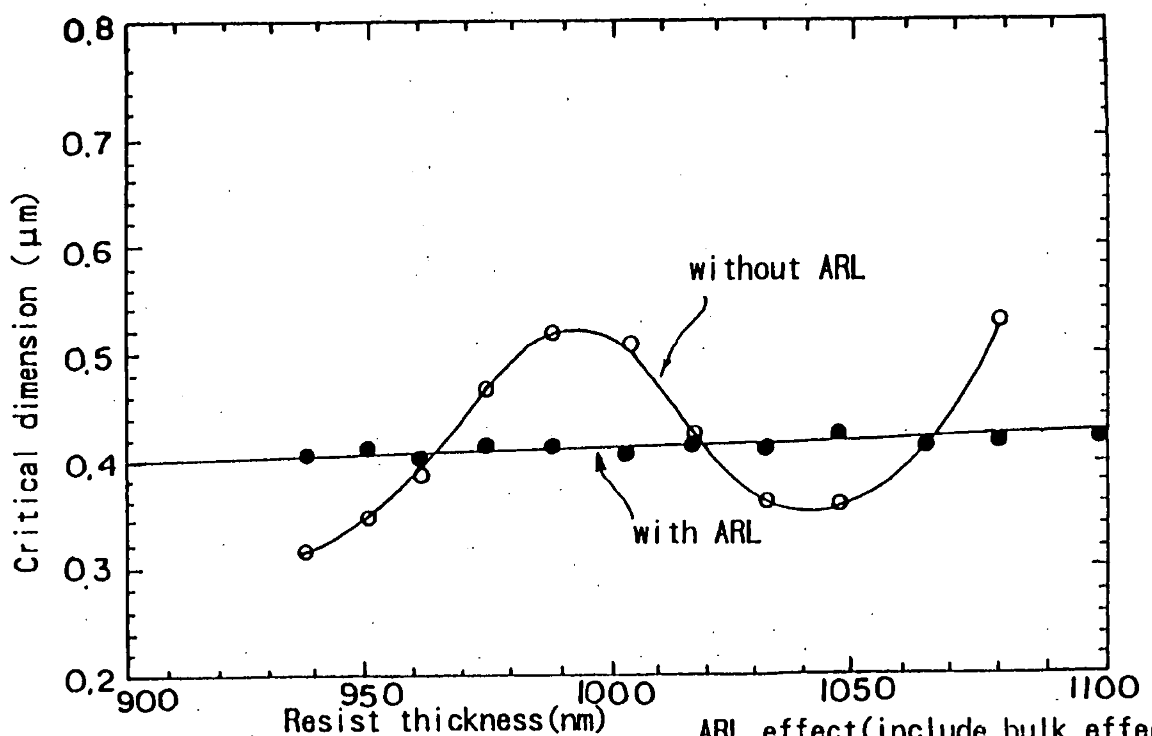
Fig.63

Anti-reflective effect of the film formed in Example 90 (simulation) on Al-Si



Conditions for simulation: Photoresist: n=1.80, k=0.011
SiOxNy(Hz): n=2.09, k=0.87, d=24nm
Al-Si: n=0.089, k=2.354

Fig.64 Anti-reflective effect of the film formed in Example 90 (measured m i line lithography) on W-Si, 0.44 μmL/S(k_1=0.63)



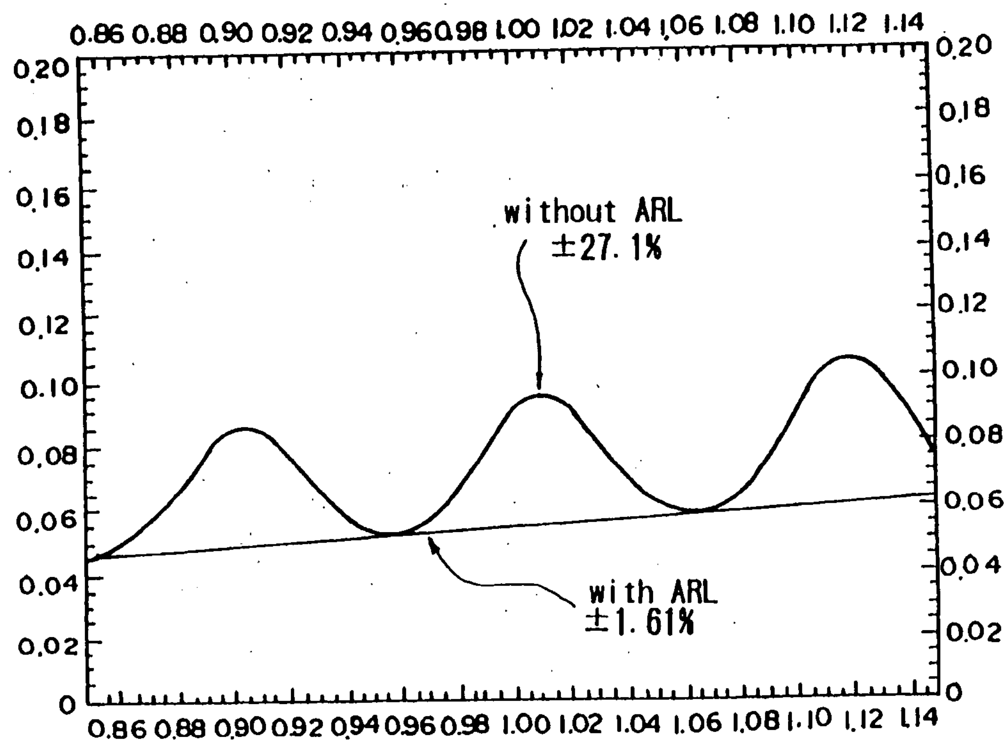
Conditions: Substrate: W-Si
(n=3.067, k=2.793)
AR: SixOyN(Hz)
(n=2.58, k=0.42, d=30nm)
Photoresist: naphtoquinondiagide resist
(n=1.693, k=0.0032)

ARL effect(include bulk effects)

	without ARL	with ARL
Max	0.530	0.427
Min	0.316	0.404
Swing ratio	±25.3%	only bulk effects

Fig.65

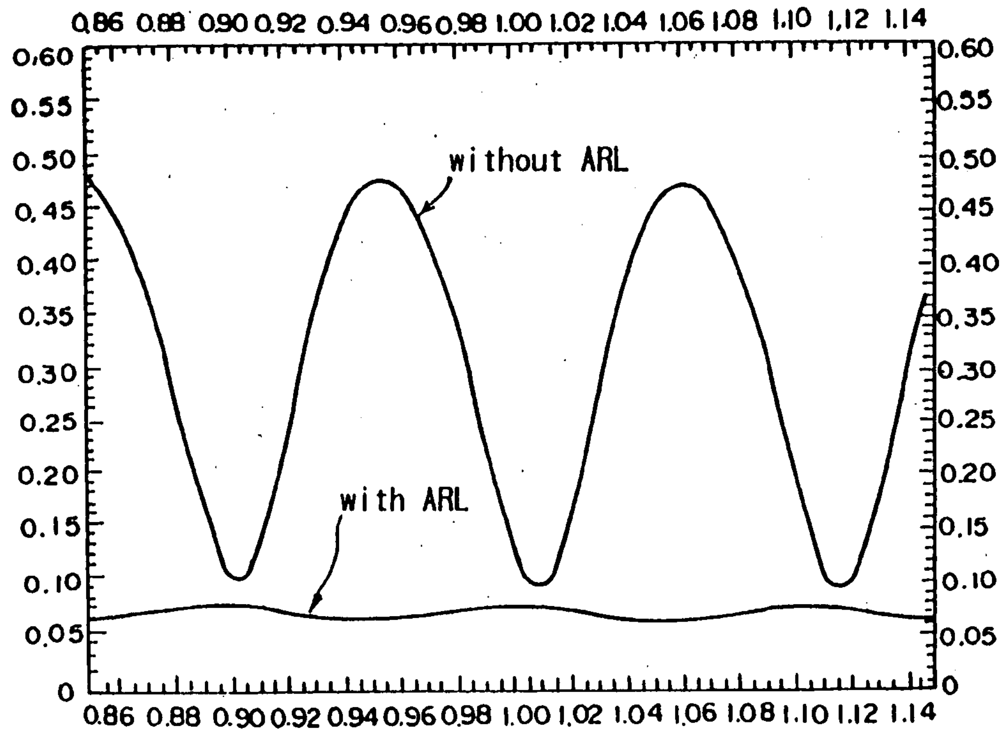
Anti-reflective effect of the film formed in Example 90 (absorption ratio)



Conditions: n_{arl}=2.58
k_{arl}=0.42
d=30nm
n_{PR}=1.7
k_{PR}=0.00174

Fig.66

Anti-reflective effect of the film formed in Example 90 (reflective ratio)



Conditions: As same in Fig64

Fig.67

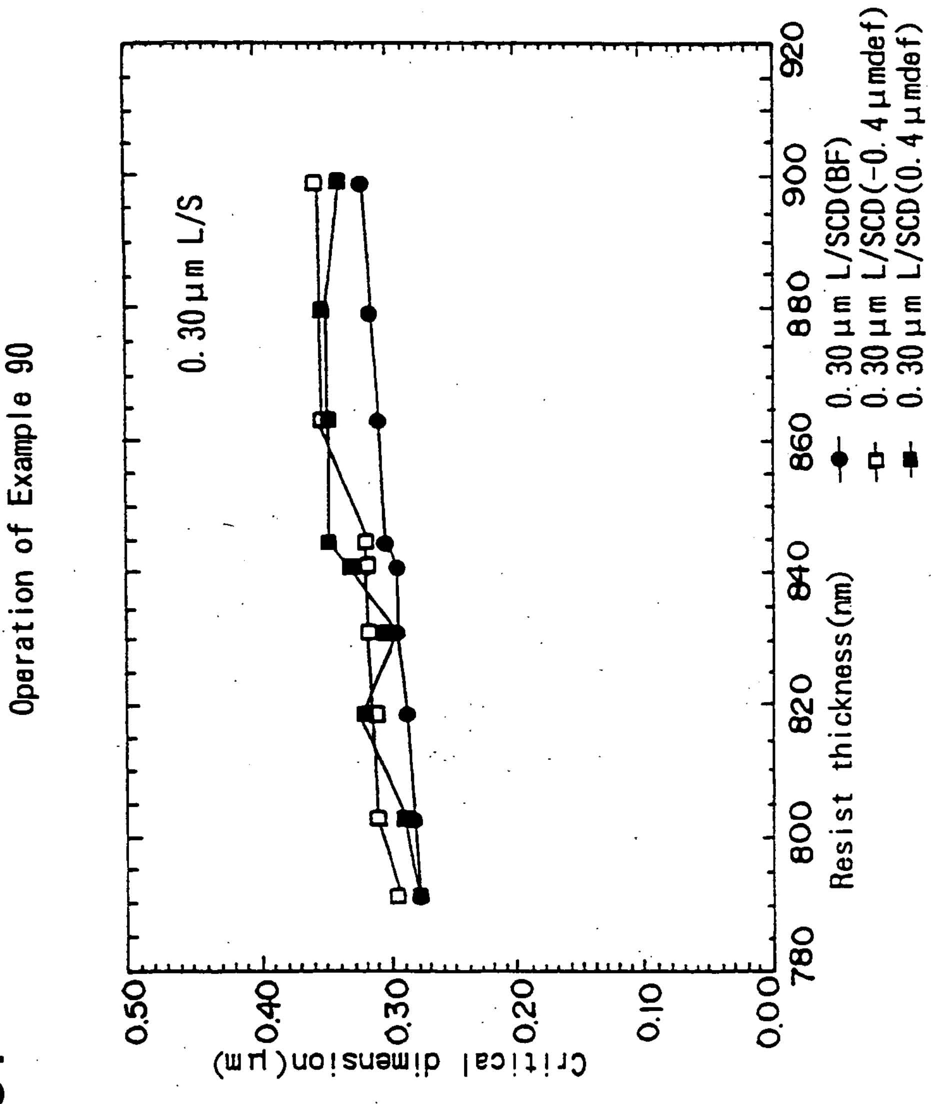
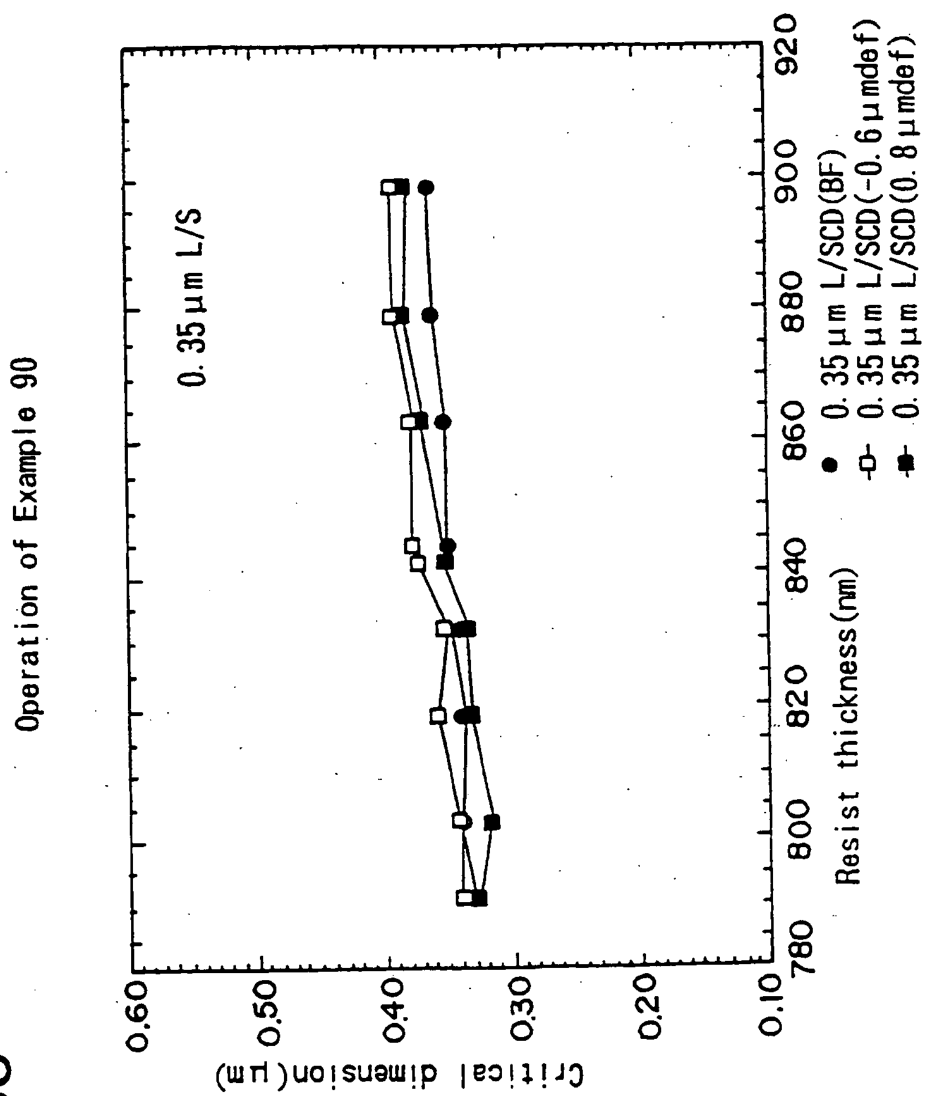

Operation of Example 90
0.30μm L/S
Critical dimension(μm)
0.50
0.40
0.30
0.20
0.10
0.00
780
800
820
840
860
880
900
920
Resist thickness(nm)
0.30μm L/SCD(BF)
0.30μm L/SCD(-0.4μmdef)
0.30μm L/SCD(0.4μmdef)

Fig.68


Operation of Example 90
0.35μm L/S
Critical dimension(μm)
0.60
0.50
0.40
0.30
0.20
0.10
780
800
820
840
860
880
900
920
Resist thickness(nm)
0.35μm L/SCD(BF)
0.35μm L/SCD(-0.6μmdef)
0.35μm L/SCD(0.8μmdef)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

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(71) Applicant: **SONY CORPORATION**
7-35, Kitashinagawa 6-chome
Shinagawa-ku
Tokyo (JP)

(72) Inventor: **Ogawa, Tohru, c/o Sony Corporation**
7-35, Kitashinagawa 6-chome
Shinagawa-ku,
Tokyo (JP)
Inventor: **Gocho, Tetsuo, c/o Sony Corporation**
7-35, Kitashinagawa 6-chome
Shinagawa-ku,
Tokyo (JP)

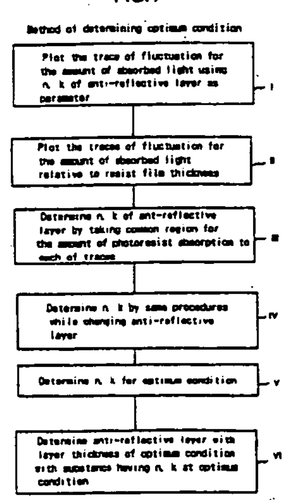
(74) Representative: **TER MEER - MÜLLER - STEINMEISTER & PARTNER**
Mauerkircherstrasse 45
D-81679 München (DE)

(54) **Method of determining optimum optical conditions for an anti-reflective layer used in a method of forming a resist pattern.**

(57) A method of determining an optimum condition of an anti-reflective layer upon forming a resist pattern by exposure with a monochromatic light, a method of forming the anti-reflective layer therewith, a method of forming a resist pattern using a novel anti-reflective layer obtained therewith, and a method of forming a film.

The optimum condition of the anti-reflective layer is determined and the anti-reflective layer is formed by the methods described below. Further, an optimal anti-reflective layer is obtained by the method which is used for forming the resist pattern. The method comprises (I) forming an equi-contour line for the amount of absorbed light regarding a photoresist of an optional film thickness using the optical condition of the anti-reflective layer as a parameter, (II) conducting the same procedure as in (I) above for a plurality of resist film thicknesses, (III) finding a common region for the amount of absorbed light with respect to each of the traces obtained, thereby determining the optical condition for the anti-reflective layer, (IV) applying same procedures as described above while changing the condition of the anti-reflective layer, thereby determining the optical condition for the anti-reflective layer, and (V) determining the optimum optical condition such as the kind and the thickness of the anti-reflective layer under a certain condition of the anti-reflective layer.

FIG.1



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EUROPEAN SEARCH REPORT

Application Number
EP 93 11 3219

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	PROCEEDINGS OF THE SPIE - CONFERENCE OPTICAL/LASER MICROLITHOGRAPHY V, vol. 1674, 11 March 1992 - 13 March 1992 SAN JOSE, CA., USA, pages 362-375, TOHRU OGAWA ET AL. 'Novel ARC optimization methodology for KrF excimer laser lithography at low K1 factor' * abstract * * page 364, paragraph 2.3 - page 366, paragraph 2.4; figures 1,5-10 *	1,5,14	G03F7/09 H01L21/027
X	EP-A-0 098 582 (TOKYO SHIBAURA DENKI K.K.) * page 3, line 27 - page 4, line 1 * * page 4, line 29 - page 6, line 4; figures 3-5 * * page 6, line 31 - page 7, line 7; claims 1,2,7 *	11,12	
A		2,4,6,8,22	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
X	EP-A-0 379 604 (SIEMENS AG.) * column 1, line 1 - line 43 * * column 2, line 31 - line 36 * * column 3, line 1 - line 9 * * column 4, line 6 - line 14; figure 3 * * column 4, line 21 - line 28 *	11,20	H01L G03F G02B
A		4,13	
X	US-A-4 451 969 (ARUP R. CHAUDHURI) * column 2, line 37 - line 47 * * column 4, line 25 - line 68; figure *	22	
A		4,11,12	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	10 May 1995	Klopfenstein, P

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
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& : member of the same patent family, corresponding document

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 3219

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	THIN SOLID FILMS, vol. 164, 1988 pages 375-379, H. ZORC ET AL. 'Medium optical index material tailoring by plasma-enhanced chemical vapour deposition' * page 376, paragraph 2; table 1 *	33-35	
X	PATENT ABSTRACTS OF JAPAN vol. 14 no. 222 (E-0926) ,10 May 1990 & JP-A-02 055416 (SEIKO EPSON CORP.) 23 February 1990, * abstract *	33,34	
A		35	
X	JOURNAL OF APPLIED PHYSICS, vol. 62,no. 11, 1 December 1987 pages 4538-4544, Y CROS ET AL. 'Optical properties of plasma enhanced chemical vapor deposited silicon-oxynitride films' * page 4538, paragraph I * * page 4539, paragraph III; table I *	33,34	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
A		35	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	10 May 1995	Klopfenstein, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 3219

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
P,X	OPTICAL/LASER MICROLITHOGRAPHY, SAN JOSE, CA, USA, 3-5 MARCH 1993, vol. 1927, pt.1, ISSN 0277-786X, PROCEEDINGS OF THE SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, 1993, USA, pages 263-274, OGAWA T ET AL 'Practical resolution enhancement effect by new complete anti-reflective layer in KrF excimer laser lithography' * abstract * * page 264 - page 265; figures 1-5 * * page 266, paragraph 3.2 *	1,5,14, 22,33-35	
P,A		4,8-10, 13, 17-19, 23-32	

P,X	PROCEEDINGS OF THE SPIE - CONFERENCE OPTICAL/LASER MICROLITHOGRAPHY VI, vol. 1927, 3 March 1993 - 5 March 1993 SAN JOSE, CA. USA, pages 275-286, HAN J. DIJKSTRA ET AL. 'Optimization of Anti-Reflection layers for deep UV lithography' * page 278 - page 283; figures 2,3,5; tables 1,2 *	11,12, 20,21	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
P,A		1,4,9, 13,14, 18,23, 24,27,28	

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The present search report has been drawn up for all claims

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Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	PROCEEDINGS OF THE SPIE - CONFERENCE OPTICAL/LASER MICROLITHOGRAPHY V, vol. 1674, 11 March 1992 - 13 March 1992 SAN JOSE, CA., USA, pages 350-361, Y.SUDA ET AL. 'A new anti-reflective layer for deep UV lithography' Abstract * page 352, paragraph 3 - page 353; figures 1,8,10,11 *	1,5,14	
A	PATENT ABSTRACTS OF JAPAN vol. 15 no. 464 (E-1137) ,25 November 1991 & JP-A-03 200367 (SANYO ELECTRIC CO LTD) 2 September 1991, * abstract *	4,33,34	
A	FR-A-1 534 173 (GENERAL PRECISION INC.) * page 1 - page 3; figure 2 *	2	
T	DE-A-43 11 761 (MITSUBISHI DENKI K.K.) 21 October 1993 * page 5, line 29 - page 6, line 15 *	4	TECHNICAL FIELDS SEARCHED (Int.Cl.5)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	10 May 1995	Klopfenstein, P

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European Patent Office

EP 93113219

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid,

namely claims:

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

☒ LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions,

namely:

1. Claims 1,5,14: A method of determining the optimal optical conditions for an anti-reflective layer in a method of forming a resist pattern.

2. Claims 2,3,6,7,15,16: A method using a SiO_x anti-reflective layer with specific optical indexes.

3. Claims (4,8,13,17),(9,10,18,19), (11,12,20,21), (23,25),(24,26),(27,29,31),(28,30,32,34) (7 independent claims): A method using a $Si_xO_yN_z$ or Si_xN_y anti-reflective layer characterized by specific optical indexes or underlying materials or compositional features.

4. Claim 22: A method using a silicon oxide or silicon nitride or silicon oxide nitride or silicon carbide anti-reflective layer containing hydrogen.

5. Claims 33-35: A method of forming a film by vapor phase deposition using a raw gas containing at least silicon and oxide elements.

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid,

namely claims:

☐ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims,

namely claims: